AMERICAN ADDRESSES

Sir Berkeley Moynihan

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BY
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TO

G. W. CRILE

PREFACE

THE papers included in this volume were read in Chicago and elsewhere during October and November, 1917. I hope they may help my American colleagues to some appreciation of the causes and conditions of the war, and afford some help to them in their treatment of the many new phases of surgical diseases with which they will be called upon to deal.

The papers represent not only my own views and experience, but those of others also. In forming my opinions upon the several matters discussed I have received very great help from the many consultations and discussions I have had with many of my friends in the different war zones of France and England. I may most appropriately and appreciatively quote—

"I have gathered a posie of other men's flowers
And nothing but the thread that binds them is mine own."

BERKELEY MOYNIHAN

November, 1917

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THE CAUSES OF THE WAR

CONVOCATION ADDRESS TO THE AMERICAN COLLEGE OF SURGEONS

"How happy is he born or taught,
That serveth not another's will;
Whose armour is his honest thought,
And simple truth his utmost skill!"

What is this war about? How has it come about that America and England are standing side by side in so bitter and stern a conflict against Germany and Austria? What are the strange circumstances which at last have ranged against the Central Powers of Europe almost all the free peoples of the world?

No doubt many answers, each conflicting with the rest, and yet each containing some small grain of truth, may be given to these questions. We may say, for example, that we fight against the continued aggression of Prussia and those other German and Austrian powers whom Prussia has inspired and instigated. No one who reads history with an unbiased mind can doubt that Prussia has increased, often if not always, at the expense of other states by acts

of sudden and unprovoked aggression. Certainly, from the hour when, in the midst of peace, Prussia laid rude and violent hands upon Silesia, her own aggrandisement, her territorial increase, and her growth in power and possessions outside her own borders, have been due to the wars she has waged. War is the National industry of Prussia; it is her means of acquiring wealth; it is by her military successes that she has enlarged her borders, added to her own infertile lands, solidified her gains, and been able to prepare for a still further attack upon her next chosen victim. States may advance in power, and in all that power implies, in wealth and prosperity, and in the happiness of its citizens, by acquisition from without, or by growth from within, by discovery and development of its own resources, and by directing all the energies and talents of its people to its own internal advancement. No state in history can compare with Prussia in its exploitation of the doctrine of plunder; the doctrine of taking because it has the power, and of keeping because it has the strength to do so. Quite consciously and quite unabashed she has possessed and gloried in the possession of this power, has fostered it, and with deliberate and frank intention has exerted it at her own time and for her own ends. She sought dominion,

she had her own confident and unwavering conviction of her power to seize it, and of all the means by which it was firmly to be held. From her point of view she had every reason to think her methods were right. Not for one instant, of course, did she call in question the principles, or doubt the ideals, which underlie her action. The Greatness of Prussia, the Dominion of Prussia, which grew at last into the lust for World Dominion by Germany, were embedded deep in the very fabric of the Prussian mind. Perhaps not so much embedded as incorporated, distributed, that is, equally and generously through every part of her national consciousness. The successes of 1864, 1866, 1870 are, even at this long distance of time, stupendous not so much in their material results, remarkable as these were, but in their disclosure of a mighty and well-ordered power that seemed to move irresistibly along a predestined path, to a goal which had been long foreseen and calmly and securely chosen. Never, it is safe to say, in warfare before had plans been so carefully laid, never had they matured in more perfect accord with such design. In this war also we learned without surprise that the official communiqué, published in Berlin in the first weeks of the war, told with laconic precision that "everything proceeded according to plan." If anything on earth was in-

fallible, surely, said the German nation, our army and its leaders are infallible. The motive of the war, if this answer were true, would be Germany's ambition.

Or, we may answer my question differently. We may say that Germany had grounds for her belief that she was a nation encircled by hostile powers, jealous of her splendid growth, of her swift acquisition of wealth, of that armed strength afloat and ashore, to which she added daily. And we may listen to her passionate utterance that her access to blue water was barred, her commerce crippled, that she was denied that "place in the sun" to which her might entitled her. We can understand Germany, though we cannot for one instant agree with her when she says that for her this was a war of defence, that she is fighting for a way out of the strong iron bastion that had been built up around her frontiers. Prussia in her early days never had a frontier, and her first conscious act as a nation was to forge out of her army the frontier which nature had denied to her. The motive of the war, if this answer were true, would be Germany's fear: fear, the black godmother of cruelty.

These are the conflicting answers that may be given by one side or the other. But anyone who has

given thought to the matter (and who has not?) must agree that whatever else this ghastly conflict now is, it is in simple truth, not a clash of merely material interests. This is a moral war. It is a holy war if ever there was one. It is deep down a war between conflicting and discordant and unconformable moral systems. It is a war, therefore, in which a real peace cannot come by compromise; for you cannot come to any terms but one, with that which you feel to be a principle of evil, with that which you feel in your innermost soul to be the deadliest enemy to mankind, and the most menacing blight with which civilization has ever been threatened.

What then are the issues at stake? How is the question I put to be answered?

Let us examine the principles which appear to underlie the action of the protagonists in this very whirlwind of war. The principle ground into the very fibre of the German peoples, accepted by them, gloried in by them, worshipped by them, inspiring them, is the principle of *Tyranny*. What exactly is meant by that? It implies a complete surrender of individual rights and liberties, and an unquestioning submission of them to a power exercised exclusively from without. This power may be called the State, or the Dynasty, or it may be a ruling caste. It is

something outside and above the individual, uncontrolled by him, owning no allegiance to him, but directing him and ordering all his actions in a manner and with a purpose which, he is told, are for the benefit not only of the paramount authority, but incidentally or consecutively of himself. Tyranny, that is to say, is the power exercised by an irresponsible autocracy; it is the supremacy of the State carried to its ultimate expression; and it is by implication an attribute of every individual in the State. This is no ignoble creed, and Prussia, let us tell it to her credit, has made a robust philosophy of it, and has gained the staunch and willing adhesion to it of almost every man in her nation. Vigour and efficiency are the practice of this creed; that "might is right" is the law by which it lives; courage is its inspiration; in success is found its ample apology. Treitschke tells us in terms that cannot be misunderstood that the "State is Power," and that nothing can conflict with the State's duty to uphold and extend itself by the exercise of might. This is in truth the "Religion of Valour."

Over against this what have we to set up, on our side, as our standard? What is the principle by which we are sustained? whence do we derive our soul's refreshment? It is hard to find the precise word, but none fits so well as *Liberty*. And by liberty

we mean here the inalienable and indestructible right of every human being to express himself, to be himself, to develop from within. The relationship of a man endowed with, and encompassed by, such liberty, to the State is simple enough. The laws which govern and control him are laws which he himself has helped to make, and to which he, with others like him, willingly conforms, not so much because the laws are good, but because they are laws which he, and those who have gone before him, have in freedom, imposed upon themselves. This is democracy. To us as surgeons practising a scientific profession the conflict between these irreconcilable principles is of deep significance. For let us consider their application to education.

Tyranny, in the sense in which I have used it, means that every unit in the nation must receive an imprint, a stamp from the State, indicating his training and value. The doctrine of tyranny implies that for the service of the State every individual must receive such training as will fit him to be, and ensure his becoming, a willing and obsequious servant of the State. This necessarily implies the possession, or the capture by the State, of all the machinery of education. Is this, in fact, what has happened in Prussia and in Germany? There can be no doubt

whatever about the answer. The German educational machine is an absolutist machine, a possession of the central authority, exactly as is the navy or the army. Bismarck said, on August 11, 1893: "The school is an important part of Germany's national institutions. The German school, like the German corps of officers, is a specifically German institution which no other nation can easily copy. In the course of the last few decades the seed sown by the schools among the youth has borne fruit and has given us a national political consciousness which formerly we lacked. The most potent influence which the body of the teachers brings to bear upon German national education consists in this, that when the German teacher receives the child its mind is like a white sheet of paper. What the teacher writes on it is written with indelible ink. It remains for life. The youthful soul is soft and receptive, and we all know that we never forget what we have been taught between the ages of seven and fifteen years. The lessons then impressed upon us guide us forever. In this receptivity of youth, in the fact that the minds of people may at an early age be molded for all time, lies the power which the German teachers have over Germany's future. As I have said on a former occasion, he who controls the schools controls the future."

Education in Germany may be obtained in public or in private institutions. The last figures available showing the number of students attending German schools are for the year 1911. In that year there were 11,050,620 pupils in public schools, as against 126,278 in private schools—a proportion of 88 to 1. In Prussia alone the numbers were 6,674,989 in public schools to 8996 in private schools—a proportion of nearly 750 to 1. The importance of this gigantic difference is realised when it is understood that the teachers in the public schools "have the rights and duties of State officials"; that is, they may prune themselves with all the petty arrogance which is inseparable from a Teutonic official, but they must submit to that iron discipline which regulates their conduct, and must curry favour with that stern and unbending authority upon which their academic career entirely depends. And this firm and unrelenting grip fastens also upon the universities and upon every professor. None can hope for promotion, or for those titles and distinctions which are so precious, unless he is in all essential things in agreeable conformity with those who exercise control. "No scientist, however eminent, can hope to obtain a professorship in Prussia if he is *persona ingrata* with the government, and a professor who opposes the government, unless he

acts with the greatest moderation and circumspection, is likely to lose his position and income." The German government exercises practically unlimited influence over the universities rather by indirect than by direct means. The university professors can be controlled or cajoled by the Minister of Education, who exercises vast powers and distributes a valuable patronage. All of us know how influences of this kind may be wielded, and how swift and heavy may be the visitation for a grave offence.

The State, then, in Germany not only owns the educational establishment, but elects and trains the teachers in the several grades of schools, confers upon them the rights, and exacts from them the duties, of State officials, and finally exerts a firm and purposeful direction upon the instruction given to all pupils. For its own objects the State uses the didactic weapon with a strong hand and a far-seeing and ruthless purpose, and she makes no secret of her intentions. The Kaiser himself, in an educational address, has said, speaking of the use of the school as a political weapon: "If the school had done what must be demanded of it, it should at once and on its own motion have undertaken the fight against social democracy. The teaching boards ought to have combined and ought with energy to have instructed the growing generation in

such a manner as to furnish me with material with which I can work within the State. Then it would have been easy to overmaster quickly the Socialist movement"; and again: "Men who support Radical Utopias can as little be employed in education as they can be employed in the government offices"; and that this view of the duty of the State to use this instrument still continues we have the authority of Friedel, who states that today "both the Prussian government and the Imperial Government of Germany were stealthily taking every step towards a centralization of control of German education in order that under the political influences of the Imperial Government every school, every university, and every educational outpost of Germany after the war might respond at once to instructions from the centre, and use their intellectual propaganda for Germanic ends." German education, both before the war and since the war began, has indeed been a master weapon in the hands of the military party, and there is, as we learn without surprise, every intention that the strength of this implement shall be used as ruthlessly as ever in the service of the State. There is evidence, M. E. Sadler tells us,—and there is no better informed authority,—that in Germany there has recently been a huge wave of national feeling expressing

itself in demands for emphasis upon those subjects which would fill the minds of boys and girls with a sense of glory in the German past, of confidence in the German future, and with some contempt for Germany's enemies. These efforts are not restricted to domestic matters. We know that measures are being taken to extend the sphere of German influence, through the medium of education, in Turkey, and the Balkans, and in Latin South America, not only by the government, but by the business men and by instructed public opinion.

This brief exposition of Germany's educational aims does not attempt, or desire, to deny the many and great achievements which can most justly be placed to their credit. The average German student was well taught, even if the things he learned were not always a sober reflection of the truth; even if truth were held of less account than expediency. A multitude of talents may not inaccurately describe the German nation, considered from the educational standpoint. A nation so organized and so instructed may, indeed, as all the world has learned, be either a mighty influence for good, or a strong and sinister implement of mischief. "Opinion in Germany," says a well-informed and credible writer, "from the cradle to the grave, has been controlled and directed by the military, Macht-

politik, and the policy of ruthlessness in warfare is, therefore, unanimously advocated by soldiers and citizens, scientists and clergymen, merchants and Roman Catholic priests."

This is, in my belief, a fair statement of the effect of the principle of tyranny applied to educational methods and propaganda.

The principle of liberty acts far otherwise. This implies the desire and intention of those responsible for the teaching of the nation that the individual shall develop, morally or intellectually, from within; that by education he shall be given the power and enjoy the opportunity of self-development and learn the manner of self-expression. Where Germany seeks to nurture in each child the gifts, and the measure of those gifts in so far as they may be of direct service to the State, the system of liberty desires the fullest development of all the natural powers in order that in their own measure and stature they shall be available for the common good. And so by the German method instruction of the hard-and-fast kind extends to all branches of learning. I remember well, only a month before the war, discussing with a distinguished German colleague some aspects of English literature and some gifts and qualities of the men who had bequeathed to us the splendid heritage which is

the chief glory shared by all who speak our common tongue. I was struck not only by the variety, but also by the rapidity of the judgments expressed. When, for example, Galsworthy was mentioned, there came a clear and crisp opinion, precise, uncompromising, devoid of qualification or of illustration. I wondered at the swift precision until a few minutes later we came to speak of Oscar Wilde. Now Wilde, with all his subtly interwoven virtues and defects, cannot be expressed in an epigram or summarised and dismissed in a phrase. Yet in this case again I had to listen to a curt and neat and exact survey of Wilde's position among modern authors. I was lost in stupefaction, but had the curiosity to ask if my adversary in this friendly debate had read much of Wilde's work. And quite frankly the confession was made that not one volume of this author had been read. The opinions to which I had listened with real interest were, so I learned, those held in Germany, taught in her schools, and humbly accepted as apt and accurate. Even in a matter so remote from any bureaucratic importance there was, so to speak, the official and authoritative opinion. Here, as often before, the German people would seem to hold a "herd" opinion upon many problems, and to express them in identical phrases. This little illuminating

experience seemed to me to have its own, and a very real, significance, and to contrast quite sharply with what would have happened if I had been discussing this matter with a fellow-countryman. He indeed might never have read Wilde, though probably he would have seen one of his most charming plays; if he had read Wilde he might not have thought it worth while to form an opinion about him as a writer of English prose; but it is quite certain that if he expressed an opinion it would be his own opinion, whether right or wrong. "A small thing but mine own" he might have said apologetically.

Is then the German system really educational? It is, I believe, a mistake to assume that the present highly organised, well-planned, systematic instruction in the German schools really educates the German people. It puts upon their minds too many ready-made opinions, disposes them too easily to accept the judgments of experts on subjects with which they are not familiar; it departmentalizes German opinion and prevents the ordinary German citizen from forming his own judgment on the profoundest political and moral issues while giving him an overflowing consciousness of excellence.

The system of liberty, on the one hand, desires rather to develop and strengthen the character of the

future citizen; the system of tyranny seeks to train and stamp the intellect with a certain quality. It is free natural growth, on the one hand; it is repressive and specific culture, on the other.

The one comment, or perhaps I may without injustice say the one unfavourable criticism, that I have heard passed, in Germany and elsewhere, about our English system of education is that we place too much stress upon, and indeed waste most precious and irreclaimable time upon, the playing of games. In every English school much is made of this playing of all team games. In my day, and I hope it is so still, more was thought by his school fellows of the athletic achievements of a boy than of his intellectual prowess in the schools. In the development of a boy's character, along the lines which in my country most fathers wish their boys to go, the playing of games is the most powerful and salutary influence. The games are those in which a boy who is by nature an egoist learns that it is the right thing to play for his side. He learns that it is not individual success that counts, but victory for his team. Self is merged in the side for which he plays. And by degrees he learns another lesson more valuable still. It is that, though quite rightly he may strive for victory, it is not only victory that counts. He learns to play not for the

goal, but for the game. He finds that it is a nobler thing to play cleanly than it is merely to win. And he finds, too, not only in his youth, but through all his life, that the finest epitaph that any man can earn is this, "He played the game"—not, I beg you to notice, "He won the game," or that he achieved this or that most coveted honour or distinction, but just simply that he "played" the game. Even in this war I think we have an illustration of this very point. Many new devices have come to the aid of all the armies, and such science as each nation possesses has been called in to aid the combatants. Is it not interesting that all the dirty dodges, the gas attacks, the liquid fire, the bombardment of open towns, the metamorphosis of neutral embassies into bacteriological laboratories, the unrestricted use of submarines, have all come from one side? And is it not interesting that so many of the real and honest devices, barrage fire, tanks, hand grenades, have come from the other? It is satisfactory to know, however, that when the Allies are compelled to retaliate, as they did very tardily and regretfully, for example, in the matter of gas attacks, the morbid ingenuity of the German recoils upon himself very heavily. In these matters, so far as we have had to make a rejoinder, the German is now surpassed both by the French and

ourselves. It would, as a piece of practical policy have paid the enemy better to have "played the game." The response may indeed be made that this notion of playing the game for what the game is worth is not enough; that victory and the fruits of victory are really the ends in view. But we as surgeons know better. We are at work in our profession for the sake of the task, not for the tribute that we exact for our services. Our delight and our recompense are in the good work we are able to do, not in any paltry or imperfect pecuniary recognition of our value. We practise that in a profession, not a trade, and life is the most splendid and the most arduous profession of all. The development of a man's character, which allows the fullest expression of a man's life, is, therefore, the motive and the mark of all methods of liberal education. It is the "drawing out" of something from the man himself (for that is what education means), as contrasted with the something driven in, by the usages of the method of tyranny. It is something added to the mere building up and shaping of a man's mind. There is a charming legend in one of the Apocryphal gospels. Some little children were sitting by the wayside playing, and making mud sparrows, when the Holy Child passed that way and took the sparrows in his hands, warmed them in his

bosom, breathed upon them, and released them to fly into the heavens. This should be the impulse of liberty—an influence carrying life and freedom and ecstasy with it. And what may we hope the qualities of a whole nation to be whose individual members are brought up in these ideals and by these methods? Let us hope that they are justice in administration, steadfastness, a spirit of tolerance, and moderation in victory.

And in the practice of our profession am I in error in thinking that I have noticed among those trained in the ideals of liberty a gentler approach to the individual patient, a more anxious consideration for his welfare, and a more tender sympathy and compassion for his suffering than is found among that people for whom technical skill counts more in public esteem than do qualities of character?

We have then in this war, as I believe, these conflicting and contending systems, tyranny and liberty; autocracy and democracy; control and repression from without, growth from within. And I am deeply persuaded that an issue for the world of science, almost as critical and as grave as any I have mentioned, is at stake in our future. Tyranny long exercised must mean a restriction of the intellectual outlook, a fettering of our thoughts to customs and to

ordinances that cramp our minds, an atrophy from long disuse of that quality of mental effort which makes for originality. Tyranny implies the negation of scientific progress, though the unrestricted exercise of its formulæ may arrange in orderly precision all the knowledge that others have acquired. Tyranny means at last intellectual sterility and death. How impossible it is for a nation held in the grip of tyranny to give its citizens intellectual freedom, great though its desire may be to do so! Progress in science must, first and last, depend upon the unrestrained freedom of exercise of all the faculties of the human mind. Of these, imagination is perhaps the chief. Imagination is the mother of fact. Or, one may say, it is the scaffold upon which one stands to build the structure of truth. Imagination, as Keats tells us, may be compared to Adam's dream—he awoke and found it truth. It cannot surely live in the narrow restrictions and in the dank and stifling air where the noxious weed of tyranny thrives. For, hamper it as you will, thought in the long run must have its way, which is the way of challenge and inquiry. Nor, I think, can any work of enduring value come in the absence of intellectual morality, the very existence of which is threatened by that surrender of truth to expediency of which I have spoken. And I believe

that the history of Germany in the last forty years is the most convincing argument that can be brought in favour of this thesis. In all this period she has displayed amazing industry, ungrudging toil; she has organised and tabulated and made accessible to all peoples the scientific work of every nation. She has, indeed, been the intellectual clearing-house of the world. It would be useless to belittle and impossible to deny her intellectual value to the world. The best of her is diligence. But her own original contributions to science are, I believe it to be beyond dispute, the slenderest of any of the great nations of the world. Tyranny is not a force to set ideas in motion. Under a system of tyranny intellectual salvation can come only from revolt. How else can we account for the eternal freshness of the Jewish mind, and for the splendid achievements of that race which, tyrannized by every power, has kept its own religion and lived its own intellectual life, not by submission, but by resistance to those who held its men in bondage? Was not Pilgrim's Progress the cry of an unfettered soul, and not of the body restrained by the bolts and bars of Bedford Gaol? And was it not in Patmos that St. John the Divine beheld the visions of the Apocalypse?

In this war, as I see it, we are fighting therefore

for liberty: of the two discordant systems of morals, one only must triumph and survive. If we compromise with that which we believe to be a principle of evil, a precursor of moral and intellectual death and dissolution, we are false to those who have given their most precious lives that truth might conquer at the last, but more than this, we are false to those who come after, we are robbing them of their birthright, we are shackling for generations to come the minds and the souls of men, we are failing in our plain duty to humanity.

GUNSHOT WOUNDS AND THEIR TREATMENT

Surgeons who were responsible in the early weeks of the present war for the treatment of the wounded soldiers coming home from France are, I think, never likely to forget their experience. There were wounds of many dimensions and of every tissue, all characterised by the most profuse and offensive suppuration. No one in active work had ever met with cases like all of these. Whether a surgeon had practised "aseptic" or "antiseptic" surgery, he had been able to secure with gratifying constancy a blameless healing of the wounds he had made; he had rarely seen a profoundly septic wound, and the methods he had at his disposal for dealing with them were, almost always, easily capable of reducing and controlling the infection. Suddenly he was confronted with a long succession of cases in which a raging and often a rancid suppuration was present, and he found that all the old remedies, upon which he had so comfortably and so confidently relied, were hopelessly inadequate and futile. A challenge was, so to say,

thrown to the profession, and I think we may now with due modesty claim that it has been splendidly and triumphantly met. Rebukes and taunts at our incompetence were not seldom heard in those far-off days. We were asked if Lister had worked in vain; and we were told that we had failed to learn the lesson he had spent his life in teaching.

It is interesting to read again the works of Lister, and to see how helpless he felt himself in dealing with putrefactive processes once firmly established in a wound. Lister everywhere distinguishes between the "prophylactic" and the "therapeutic" uses of antiseptics. All the marvellous achievements of modern surgery are due to the adoption, by surgeons the whole world over, of the principle of the prevention of infection in wounds about to be made, as distinguished from that of the subduing of an infection already rampant.

Lister writes: "The original idea of the antiseptic system was the exclusion of all microbes from wounds." Again, "During the operation, to avoid the introduction into the wound of material capable of inducing septic changes in it, and secondly to dress the wound in such manner as to prevent the subsequent entrance of septic mischief." Again, "In wounds already septic attempts are made with

more or less success to restore the aseptic state." Again, "In speaking of the antiseptic system of treatment, I refer to the systematic employment of some antiseptic substance so as entirely to prevent the occurrence of putrefaction in the part concerned, as distinguished from the mere use of such an agent as a dressing."

The distinction between the preventive and the curative use of antiseptics is in many respects that existing, on the one hand, between the power of a germicide as determined by experiments "in vitro," and, on the other hand, its capacity to destroy organisms when it is introduced among the living and the dead tissues of a wound. In the former there is a direct conflict, a clean fight, between the microbe and the chemical agent. Few or none of the many intervening conditions are present which have to be considered when a bactericide is introduced into a wound cavity wherein there are a multitude of actions and reactions which even now seem very obscure and are so often conflicting.

When, after the lapse of many weeks from the outbreak of war, there came a full appreciation of the several circumstances which had to be reckoned with when a soldier was wounded, it was recognised on all hands that a new and grave problem had

arisen which cried urgently for solution. What, then, were the several new factors that had to be considered in this war?

In the early days a very large number of the wounds were inflicted by rifle fire. The German bullet has a muzzle velocity of approximately 1000 yards per second. In the first 800 yards or thereabouts the flight of the bullet is not steady, but "wobbling." There are three movements—a movement forward along the line of flight; a rotatory movement, in which the bullet spins round on its longitudinal axis as a result of the "rifling" of the barrel; and a third movement, a "mouvement de bascule," of such a character that while the point of the bullet keeps steady, the base of the bullet is moving round a circle, or an ellipse, of a gradually diminishing size. The result of the last form of motion is this, that when the bullet impinges upon any substance, even the soft clothing or the flesh, the infinitely brief arrest of the point which strikes first allows the base, which is, of course, much heavier, to overtake the apex, and the bullet then lies sideways or begins to turn over and over as it ploughs its way through the soft parts. In this early part of the trajectory the missile has, of course, a great momentum; it is a heavy bullet traveling with great veloc-

ity. The consequence is that the damage inflicted is not confined to the track it rudely makes through the limb; the parts around the track are damaged also, often to a great extent, and microbes are driven deeply into all adjacent tissues. Every wound, therefore, caused by a bullet at short range consists not only in a visible tearing and destruction along the path the bullet has followed, but in a dead zone everywhere surrounding that track—a zone in which death or destruction or disintegration of the parts has occurred by reason of the tremendous concussion produced by the bullet as it tore its way clumsily through the tissues. Sir Anthony Bowlby has illustrated this by a series of exemplary instances. In one of these the kidney was wounded in its lower pole; the upper pole appeared normal to the naked eye, yet on microscopic examination the tubules were seen to be disorganised. Other examples of the widespread damage inflicted are quoted in his Bradshaw lecture. And even that is not all. The momentum of the bullet is such that to everything it encounters it imparts some of its own velocity. As we all know, shreds of the clothing or belt, or the contents of the pocket, may be carried deeply into a wound. So also are pieces of skin or muscle. And if the bullet should chance to strike a bone, the bone is not only

broken into many fragments,—the "splinter" fracture,—but to all fragments there is conveyed enough of the momentum of the bullet to convert them into projectiles also, capable of tearing a way into the softer tissues. Many of the wounds, therefore, were deep, irregular in shape, with large or small cavities, of the variety the French term "anfractuous." Into these recesses blood escapes, and, owing to the tearing and unequal retraction of cut muscles, pools of fluid may be shut off from the main track of the wound and form an ideal breeding-ground for all microörganisms, especially those which are anaërobic.

If a rifle bullet is not checked in the first 600 yards of its flight, it begins to steady down, and probably when it has traveled 1000 yards it is moving evenly. An injury inflicted then is of a quite different character. The bullet cleaves its way through the soft parts, bores a neat hole through a bone, and little destruction is done. We see many cases where the chest or abdomen is traversed from side to side, or where the neck has been pierced, and, miraculously, no real damage has been done. Examples of this form of injury were, of course, common enough in the South African war. They have been less frequent in this war because the range has often been

shorter, and the bullet, in respect of velocity and weight, is different.

During the last two years a very large proportion of the wounds have been inflicted by shrapnel bullets, hand grenades, or shell casing. The immense velocity of the projectiles, especially when a high explosive shell bursts, their irregular shape, their pitted surface and sharp edges all combine to cause wounds of very diverse forms. The track is a distorted one, the parts around it are bruised and battered or dead, and the infection carried into the wound by a piece of metal or cloth has unrestricted opportunities of spreading rapidly. In many cases large areas of the limbs or trunk are blown away; the wound remaining shows a shattered and irregular surface; the muscles are torn and crushed, or "pulped," and lose their structure. They dry rapidly on exposure, and therefore fall easy victims to a bacterial attack often of great ferocity.

The condition of the battle-fields of Flanders and of France accounts for the quality of the infective agents. Many parts of the lands over which the fighting has taken place, both before and since trench warfare set in, were cultivated assiduously by the rural inhabitants before the war. Probably no soil in Europe has been more liberally manured in efforts

at intensive cultivation. Certainly no contact between the soldier and the soil has ever been more intimate or more protracted. In the winter the whole fighting zone is, in Sir Douglas Haig's phrase, a "wilderness of mud." In the summer it rivals the desert in a sand storm; dust is everywhere. It steals into the eyes and nose and throat and ears, it grimes the face and hands, it fills the hair, it penetrates every vestment. Every projectile passing through the garments to the body will certainly be covered with the mud or dust in the clothes, and with the many organisms that respite from ablutions has allowed to penetrate the skin. All bacteriologists and surgeons are now agreed that no influence perpetuating infection in a wound is so malign as that which is harboured in the torn fragments of clothing. The physical condition of the soldier himself, when he is wounded, no doubt plays an important part in exalting the virulence of any infection which may settle upon him. Though in the best of health and physical condition at the moment of attack, he may, by the time he is wounded, have suffered great fatigue, and bleak exposure, for hours, or even days, before succour comes to him. The organisation for the collection and despatch to the field ambulances and Casualty Clearing Stations of wounded men is probably

as perfect as any endeavour can make it. But there are times, especially in a "push," when a man may lie out undiscovered for long periods. Not infrequently by reason of such causes, and on account of pain and hunger and loss of blood, he may be reduced to a state in which his power of resistance to a bacterial attack is greatly impoverished.

BACTERIOLOGY

The bacteria infesting the wounds in France have been studied by Wright, Fleming, and others. The general conclusion drawn from their work is that the microörganisms, as might be expected, are those found in highly manured soil; they are, that is to say, of fecal origin. Wright suggests, with his customary fecundity of invention, the new names "serophytes" for those organisms which will grow in normal serum, streptococci, and staphylococci, and "serosaprophytes" for those which can grow only in digested albumens. The native albumens of human serum are "protected" from bacterial development at their expense, and Wright points out that, if this were not so, human life would have been impossible. Among the serosaprophytes are the larger number of the organisms found in wounds, including all the anaërobes; the bacillus of Welch, the bacillus of tetanus, the

enterococcus, a streptococcus of intestinal origin described by the French, the bacillus coli, and putrefactive bacilli X and Y, which are the cause of the foul odour often met with in wounds. There is often a "wisp" bacillus, and a diphtheroid bacillus appears in later stages of the infection.

All these microörganisms find a most fertile medium for their growth in wounds of the character I have described. In every anfractuous wound, where the recesses are many and intricate, blood or serum may be poured out; tryptic digestion begins as a consequence of the destruction of the leukocytes, peptones are formed, and bacteria, finding everything to their liking, grow apace. From many of the wound surfaces the circulation has been cut off by the powerful stunning effect of the blow given by the projectile, and gangrene and sloughing make haste to develop. During the first four to six, or in some cases even eight, hours few organisms or none can be recovered from the wounds, either by smear methods or by cultural methods. The organisms are there, nevertheless, and, given the prodigal fertility of the soil in which they are sown, will quickly show the evidence of their growth. In this brief early period the wound is said to be "contaminated"; in all later periods, "infected." Against this attack made upon it by

immeasurable millions of organisms, how does the body protect itself? The chief defence is in the blood-serum and in the leukocytes (phagocytes). The capacity of these two, if only they have an adequate chance, may be said to be almost illimitable against all organisms but the streptococcus. The serum possesses strong bactericidal powers of its own; the phagocytes can devour bacteria greedily. But in exerting their powers both serum and white cells are apt to undergo degradation. The leukocyte breaks down and its power of tryptic digestion is then exerted upon the fluids around it, and peptones are produced in quantities which make easy the growth in them of all forms of bacteria. Moreover, the surface of the wound soon becomes "lymph-bound." A mesh of fibrin entangles the blood-cells, and a sort of matting of coagulated lymph spreads over all the surface. No fresh serum can then reach the wound, nor are fresh leukocytes available for the attack. The infective process can then proceed apace, unhindered by those powerful natural defences which for the moment have quite broken down.

THE PRINCIPLES AND METHODS OF TREATMENT OF GUNSHOT WOUNDS

(*a*) Primary Closure

Every one to whose lot it has fallen to undertake the surgical treatment of wounds in this war will agree that the most urgent need is to secure their complete closure at the earliest possible moment. In the early hours, during the period of "contamination," it is now the common practice to excise freely all damaged and dead tissue if possible in one piece. This requires some skill and no little practice to do excellently. The most careful preparation of the skin and the parts around the wound is a necessary antecedent to any operative measures. The wound, of whatever type, is excised, together with a wall not less than ⅓ inch around it. In order to make certain that all the walls of the original wound are excised, Wilson Hey has suggested and has long employed a method of staining with brilliant green, which is injected into all parts of the wound, and allowed to remain not less than two minutes. The staining of a wound not only makes a more thorough removal possible, but it also indicates those parts which cannot or may not be removed, to which, therefore, a simple mechanical cleansing must be more particularly directed. When

staining has been thought unnecessary, he tells us the final results are worse. Staining in every case is a help: it is never a hindrance. The walls of the cavity remaining after excision should bleed everywhere—perfect hæmostasis is then secured. Every soiled instrument or glove is at once discarded. The wound may then be stitched up completely without drainage, and with much confidence may be expected to heal well. The cases coming to the base hospitals in England show that in a great variety of injuries this method of the primary closure of wounds is meeting with a very remarkable success. If the operation is carried out with scrupulous exactitude and with something near to technical perfection in cases of the smaller "contaminated" wounds, where there is no loss of substance, probably not less than 80 per cent. will heal by first intention. The failure occurs in those cases where a piecemeal removal of the infected wall has been carried out, where, that is to say, there has been a frequent reinfection of the newly made raw surfaces.

There has been in all armies a certain timidity, very natural, and perhaps from many points of view very desirable, in carrying out the method of primary closure. No one who has worked, even for a brief period, in the armies in France can have failed to

realize the desperately serious results which come from the injudicious closure of septic wounds. Gas gangrene, for example, may develop in an amputated stump if even one stitch is put in to approximate the flaps. And there has consequently sprung up on all sides a fear of the premature closure of wounds. But recent experience would seem to show that, at least in the early cases, in cases reaching a well-equipped surgical unit, say within eight or ten hours, in the period of contamination rather than of spreading infection, a mechanical cleansing of the most thoroughgoing kind, carried out ruthlessly and rapidly, will allow the majority of the cases to be closed with an excellent chance of primary union. There can no longer be any doubt that many of the cases which have proved so successful under the Carrel-Dakin method, applied during the first six to eight hours, would have closed equally safely, and far more rapidly, under the method of immediate suture; and that consequently a certain degree of suffering and much expenditure of time and no little expense would have been saved. To put this statement in what may seem an extreme fashion it may be said that the Carrel-Dakin method has achieved its greatest triumphs in cases where it need not in fact have been applied. But if this opinion is true, it

must at once be admitted that one of the chief experiences which have led to its realization is the practice of this method, with great success, during many months. More than ever are we now confirmed in our strong opinion that it is the primary mechanical cleansing, after thorough exposure, and with every precaution and care, that is the supreme necessity in all cases; and that this alone, if complete, will often allow the natural defences of the body to secure the blameless healing of the wound.

(*b*) Secondary Closure

If, however, owing to one or more among a great diversity of circumstances, the patient arrives at a base hospital with a freely suppurating wound, the problem is quite different. The chance of primary closure has passed away perhaps long ago; the wound now may be covered, sparsely or thickly, with sloughs of varying size and in various stages of detachment. Layers of lymph adhere at one point, or at many, to the wound surfaces, and the discharges are thick, purulent, and offensive. The problem here is first to secure a healthy and relatively uninfected surface, and secondly to close the wound by suture on the earliest prudent occasion. What are the principles which we must now put into practice? For purposes

of tabulation and description they may be spoken of as "physiological" and "antiseptic," though, as I shall presently indicate, the difference between the two may not be so sharp as such a precise and limited statement might appear to indicate.

1. **Physiological Methods.**—These owe their origin to Sir Almroth Wright. The problem Wright set himself to solve, in the case of the septic "lymph-bound" wound, was that of rendering available, once more, all the natural defensive mechanisms possessed by the body fluids and tissues, and of exalting their power by bringing them into play in far larger quantities than are usually at our command, and in a condition which, as a result of vaccine injections, or because of the increased antitryptic power of blood-serum of a wounded man, finds them greatly augmented. We have, he says, to promote the destruction of the microbes which have been carried into the deeper tissues; we have to resolve the infiltration in the walls of the wound, and to get rid of infected sloughs; we have to prevent the "corruption of the discharges," and to inhibit microbic growth in the wound; we have to be constantly on our guard in order to prevent those active and passive movements which propel bacteria along the lymphatics, and which carry poisonous bacterial prod-

ucts into the blood; and finally, all this being done, we have to get rid of the surface infection, promote the processes of repair in the wound, and bring together the wound surfaces so that they may heal. How are these various tasks successfully accomplished?

The blood serum, as Wright has shown, possesses certain remarkable properties. Mechanically it is the agent by which phagocytes are washed on a rising tide into the wound, and chemically it has a powerful bactericidal efficiency against all microörganisms but the "serophytes," streptococci, and staphylococci; the anaërobic organisms, that is to say, are destroyed by it. The phagocytes, as Metchnikoff long ago showed us, can devour and digest microorganisms of all kinds, but, tried beyond a certain point, they perish in the fight, and liberate at their death a ferment, trypsin, which digests the native albumens in the serum, converts them into peptone, and therefore adds enormously to the cultural value of the wound discharges. The blood, however, is normally antitryptic, and this quality appears in cases of infection to be increased; there is an antidote, that is to say, to the local defeat of the phagocytes and the consequences attaching thereto. The coagulability of the serum is also increased, with the

result that a "felting" of fibrin forms on the walls of the wounds and prevents the access to the wound of reinforcements of serum and of cells. Wright's method consists in the application of a "hypertonic" solution of salt, 5 per cent. or anything over that, together with ½ per cent. citrate of soda (this is not necessary). The principle of the hypertonic method is to make use of the bactericidal power of fresh serum, which is encouraged to flow from the wound surfaces by the application to them of a more concentrated saline solution than blood-serum. A process of osmosis is at work. It is argued, or rather asserted, which is not the same thing, that serum is a fluid which will not osmose, but the fact is indisputable that when these strongly saline dressings are applied, the discharge from all the wound surfaces is increased enormously in quantity. The patient is often compelled to drink freely, so considerable may the drain of the fluid be. The discharge from the wound after the first few hours becomes clear and within three or four days may be found sterile or of low bacterial content. The streptococcus is by far the most resistant of all microörganisms; after three to five or six days it is often the only germ remaining. As I go around from one hospital to another, or from one ward to another, I think I am generally

able to pick out the cases which are being dressed by Wright's solution. The granulation tissues have a fuller, deeper colour, and the surface looks cleaner than when any other form of dressing is being used.

The blood-serum has now done its work. During this time the phagocytes have been inhibited in their action and even destroyed, as I shall presently mention. It is their aid which is, however, supremely necessary in the attack upon the serophytes. The hypertonic solution is therefore changed for an isotonic solution, which encourages the migration of leukocytes and leaves them to deal with the streptococci and staphylococci (generally few in number) that alone remain in the wound. When bacteriological examinations reveal that the wound is "clinically sterile," it may be closed by suture or its edges approximated by strapping.

The action of hypertonic saline solutions is complex, and its virtues are conflicting. It attracts water from the blood, together with all the protein substances contained therein; it inhibits leukocytic migration, prevents phagocytosis, disintegrates those leukocytes with which it is brought into direct contact, and thus sets free a tryptic ferment which digests the albumens of the blood-serum. It delays or prevents the action of this very ferment which it

has caused to be liberated. It inhibits coagulation and so prevents the sealing up of the channels through which lymph pours into the wound. It appears definitely to inhibit bacterial activity and propagation.

Various modifications of Wright's original procedures have been made. Before I left France for the first time in March, 1915, we had begun to use salt tablets, wrapped in gauze, in the wound, at the suggestion of Colonel Lawson, with the intention of keeping available in the wound cavity a constant supply of hypertonic solution. This method was afterward widely used and warmly advocated by Colonel Gray and Major Hull, who designed the "salt pack," a most useful and valuable form of dressing. After appropriate cleansing a wound may be filled with a number of salt packs, protected by a few layers of gauze from actual contact with the granulating surfaces, so as to avoid sloughing, and left for eight or ten days. The dressing becomes very offensive; but on its removal a bright, even, and healthy layer of granulations covers every part of the wound. This method is of great value in many cases of secondary hæmorrhage where only smaller vessels are involved; and in those cases where transference of the patient from one hospital to another is necessary. Colonel Sargent has recently used an

ointment made of vaselin with 5 per cent. salt added thereto; after a thorough cleansing and a sparing application of this preparation, a secondary closure of the wound will be followed by healing. The various papers of Sir A. Wright on "physiological methods" and on the treatment of wounds have helped us to realize better than ever before the immense complexity of the problems concerned with the healing of septic wounds and clearly to understand the principles upon which we must rely in order to promote union.

Antiseptic Methods.—Before any discussion with regard to antiseptic methods can be productive of good we must ask ourselves the question, "What is it we expect an antiseptic to do in an infected wound?" The answer most commonly given by those to whom I put this question is that an antiseptic acts by destroying bacterial life. But a great many qualifications must be given before such a reply can receive even a slender acquiescence. The problem of the action of an antiseptic in an infected wound is far too complex for a simple and ready answer. We know in truth very little even now of what goes on in all parts of a septic wound. But we may be quite certain that an antiseptic is never "monotropic," engaging one substance only. It may have an affinity

for the tissues forming the wall of the wound, for the serum, or for the leukocytes; or for any "corrupting" discharges which remain in the wound; or for the gauze packed into the cavity of the wound; or for the dressings applied to the surface. It may have opposing effect on different parts of the wound; it may, for example, increase proteolytic digestion in its action upon sloughs, and it may inhibit or prevent this process by its effect upon leukocytes and their emigration. An antiseptic, however potent in vitro, may be quenched by the other substances I have named and fail to influence the bacteria in any direct way. Moreover, the bactericidal power of an antiseptic is no criterion of its penetrative power. Its bactericidal power is at once profoundly modified by its contact with albumen, with which it most eagerly combines, as is also its power of diffusion, and therefore of reaching in a still active condition all the crannies and chinks among the recesses of the wound. The direct germicidal effect of any antiseptic is, therefore, almost certainly, very much smaller than many of us had supposed, and is confined chiefly or exclusively to those bacteria which are lying bare to its attack in the open wound. I have, moreover, always thought it very difficult to credit the supposition that an antiseptic, however applied, can have an efficient

action against microörganisms in a wound without producing also a very harmful effect upon the body tissues and fluids. Or, in other words, exclusive reliance upon an antiseptic to act as a germicide is a negation of all dependence upon the principles of physiological reaction of the tissues to a bacterial attack. These points will emerge more clearly in connection with a brief description of the various methods of "antiseptic treatment" adopted at the present time in the zones of the war.

Among them pride of place will cheerfully and gratefully be conceded to the "*Carrel-Dakin*" procedure. It consists, as all surgeons now know, of a free mechanical exposure and cleansing of the whole wound. This is so easy to say and, alas! so difficult in all cases to carry out adequately. The wound so made is then lightly packed with gauze into which a number of Carrel's tubes are laid; through these tubes at intervals of about two hours Dakin's fluid is instilled. Probably full realisation of the need for careful preparation and testing of Dakin's fluid is not universal; nor of the rapid deterioration in its potency if it is allowed to be heated, or exposed to the air, or stored in transparent glass bottles in warm places. The method allows of the early secondary closure of wounds, at an average period of eight to

twelve days; and coming when it did before the end of the first year of the war it is no exaggeration to describe its effects upon the treatment of wounds as revolutionary.

In what way does the Carrel-Dakin method act? Are its effects produced by reason of the strongly antiseptic properties of Dakin's fluid, or because of other properties not directly concerned with the killing of microörganisms? Or is the most excellent technique for which we cannot be too grateful to Carrel chiefly responsible in that it necessitates a greater general care of the wound, a free opening of all recesses, and that constant supervision which detects at the earliest moment any harmful development on the granulating surface? If strict dependence is placed upon the microbial curve, it would appear that the author of the method believes that progressive sterilisation of the wound is produced by the chemical action of Dakin's fluid upon the bacterial flora. The reduction in the number of organisms, even irrespective of their nature, is held to be the index of the germicidal effect of the fluid applied. Even when comparatively small quantities of a potent bactericidal fluid, like that discovered by Dakin, are instilled frequently into wound cavities covered by sloughs or granulations, the killing of

microbes may not be of serious consequence. For these organisms can propagate themselves at a rate with which the most powerful germicide could hardly "catch up" however frequently or adequately supplied. I can easily conceive of an "antiseptic," using the word in its clinical sense, which is not in the smallest degree "germicidal." I can understand, that is to say, that a wound, however gravely infected, may, by the application of some chemical substance, be deprived of its bacterial flora, in very great measure, or even completely, though no single microörganism is killed by this substance. An "antiseptic," if not germicidal (that is, not acting chemically upon the substance of which bacteria are composed), might yet render the wound sterile either by destroying the pabulum of the bacteria, so that they were unable to flourish and to propagate, or by exalting those normal powers of resistance possessed by body tissues and fluids, or by holding up the bacteria until those powers, without increase, are capable of destroying or dispelling the infective agents. Or does the action of chemical agents on the leukocytes so alter their metabolism as to produce substances which cause degenerative processes in the bacteria? That is, are involution forms of bacteria developed by the relationship of these agents to

them? The most striking effect visible to the eye in a wound treated with Dakin's solution is that the surfaces are cleaned very rapidly. Dead tissue, even large sloughs, are quickly digested away, and the surface becomes smooth, clean, and bright red in colour. In a wound not yet clean in all its parts a very different microbial curve can be drawn if smears are taken from the smooth red portion of the surface and from the edge of a slough. It is the dead tissue in the wound that keeps the septic processes going. If this is destroyed, bacterial profusion and virulence both rapidly diminish until the wound is "clinically sterile." If, therefore, a substance could be found which, without having a directly noxious effect upon bacteria, could rid the wound of all dead tissue and allow the natural defensive mechanism to have a free chance, it is possible that the wounds would heal as kindly as they do under the Carrel-Dakin system.

What appears to be a fulfilment of this supposition has been published since the foregoing paragraph was written. Donaldson and Joyce* describe a non-pathogenic spore-bearing anaërobe which acts, apparently in virtue of its proteolytic powers, only on devitalized tissues, and possibly on toxalbumins,

* Lancet, 1917, ii, 445.

and appears to possess no power of attacking healthy tissues. The powers of this organism are directed not only toward the removal of the grossly damaged tissues, but it succeeds also in attacking the microscopically damaged structures. As a result the body forces are freed from the constant menace of septic poisoning and are thus allowed to commence the work of repair. It is therefore an arguable proposition that Dakin's fluid as applied by the Carrel technic does not act only as a germicide, but also, perhaps chiefly, as a proteolytic agent, as an agent destroying those parts of the wound on which alone, or chiefly, organisms can find a place to propagate. It is, after all, therefore, the mechanical cleansing of the wound which is of the greatest importance, and the action of Dakin's fluid is perhaps very much the same as that of the surgeon's knife in these cases where the wound is excised.

The Carrel-Dakin method always stops short of perfection in asepsis. In my experience the wound is never rendered "sterile" by this method. Organisms can be found in smears and developed in culture, however long the treatment is continued in a large wound, a fact which seems to me of great significance in relation to the question of the bactericidal value of Dakin's fluid. For when fluid in the same quantity

as ever is applied, and but few microörganisms remain, their ultimate annihilation appears to be impossible. Perfect sterility, however, we have long known is not necessary for a healing by first intention; though the quality of that healing varies decidedly according to the relative infectivity of the wound. The fewer and less harmful the organisms, the more blameless is the healing. Surgeons who have worked, as surgeons should work, with a bacteriologist at their elbows, will admit they have constantly closed wounds which were proved to contain microörganisms, and yet have obtained a union of the wound that was good. Until I adopted my present technique this was a frequent experience; but many years ago I began (I was, I believe, the first to begin) the covering of the skin by tetra cloths which overlapped the skin edges, and since then I can be certain that in all clean cases the wound remains sterile to the end of the operation and a flawless healing can be confidently expected. Carrel has coined the phrase "clinical sterilisation" to indicate that condition in which organisms are so few that the wound can safely be closed and good healing obtained. Regard should, however, be paid not only to the number of the microbes, but to their nature. I do not like to find a streptococcus present when the day approaches

for the secondary suture of a wound. Carrel's method must rely at the last upon the living properties of the tissues to destroy or render innocuous the organisms still remaining in the wound when it is closed. It is true that they are few: but they are there, nevertheless, and must be overcome if the wound is to heal and to remain healed. What most surgeons have learned since the introduction of this technique is that which those surgeons who worked in association with a bacteriologist have long known, namely, that infected wounds (wounds "clinically sterile") may heal in a manner to which the term "first intention" may without injustice be applied.

What are the disadvantages of the Carrel-Dakin method? I often hear it said that it is a difficult method, requiring a special training of the surgeon, that it requires a large amount of glass and rubber tubing, bottles, etc., that it is costly in dressings, and that it calls for constant supervision or direction by the surgeon. There is truthfully no great validity in these objections. A special instruction of the surgeon is certainly necessary if he is to observe the ritual carefully, and to understand what it means; but so it may be said is a special training necessary for the surgeon when any new technical procedure is introduced. The apparatus is cheap, and is easily

obtained and lasts with care for months. If nurses are carefully trained to do the dressings with punctilious care, only that supervision is needed from the surgeon which he should give to every case. From a military point of view, however, it is a difficult method to practise on a large scale, for in our army we are compelled to evacuate a large proportion of our cases to England, retaining in advanced positions, or even at the base in France, only those classes of cases for which movement has proved disastrous. The circumstances under which Carrel worked and under which he obtained his splendid results could not conceivably be made applicable to a whole army. Some part of his success must truthfully be attributed to his opportunities for receiving cases early and for retaining them for long periods.

The chief disadvantage of the method is that if it is interrupted, it fails lamentably. When cases have to be transferred from France to England, it may for certain reasons be impossible to survey all the cases on board ship or on the train; and infection then spreads, and a reeking and rampant suppuration is present when the patient arrives at a base hospital in England. This is, it is true, an objection to a particular application of the method, rather than to the method itself. But it is the reason, I think, that the

procedure has never found a wide or general acceptance in the British army, though it has many warm advocates, and many who practise it with a success equal even to that of Carrel or of Chutro. The chief successes obtained by this method are in the early cases, in those in which treatment can begin not more than six or seven hours after the wound is made. But we are by degrees becoming less timorous in our efforts at primary closure in precisely this group and our results justify a wider acceptance and a more general adoption of this practice. In later cases the Carrel method is beyond question a therapeutic procedure of the first magnitude, but it then requires unwearying care and inexhaustible patience and a variety of favouring circumstances if the best results are to be attained.

In times of leisure the method is good; in times of war, with all the haste of war, it will often fail. "*C'est magnifique, mais ce n'est pas la guerre.*"

Rutherford Morison's Method.—This method is widely practised in the base hospitals in England, and by many surgeons is considered the most satisfactory of all. The technique is as follows: A wound, say of the arm, leading down to a compound comminuted fracture of the humerus, is freely opened up, after such preparation of the arm and of the surrounding parts

as is made in all cases about to undergo operation. The skin, that is to say, is prepared with soap, antiseptic washes (Morison uses 1 : 20 carbolic acid lotion), and spirit. The wound may be enlarged in any direction in order to make sure that no recesses in it remain undiscovered. All granulation tissue is vigourously scraped away from the wound surfaces; bleeding points are secured; obviously dead and loose portions of bone, or pieces of cloth or projectiles, are removed. The wound is packed with dry gauze for a minute or two, while towels about the wound are changed if necessary, and while the surgeon replaces all instruments, gloves, etc., with those freshly sterilized. The dry gauze is removed, the wound sponged everywhere with gauze moistened with methylated spirit. Onto the raw wound surface a thin layer of a preparation known as "Bipp" (bismuth subnitrate or carbonate one part, iodoform 2 parts, paraffin in quantity sufficient to make a soft paste). With a gauze swab this paste is rubbed well into the wound, which is then sutured from end to end without drainage. The arm is fixed on a splint and the wound left untouched for ten days. At the end of this period it is usually found healed or nearly so; another dressing is applied, and allowed to remain ten days. No further dressing is needed. The absence of frequent

dressings is an immense advantage and a comfort beyond words to an anxious, overwrought patient.

Why does Morison's method prove so successful? Is it the free mechanical cleansing of the wound that is of chief importance, or is there some antiseptic or physiological virtue in the "Bipp" as a whole, or in any of its constituent parts? It is almost certain that in the perfect mechanical cleansing of the wound lies the secret of the method. For I have treated wounds in exactly Morison's manner and have omitted the paste, and have seen the wounds heal as kindly as when it was used. If there is a virtue in the paste, in which of the ingredients does it lie? Probably in the paraffin which produces that anaërobic state in which healing can most rapidly take place. Mr. Morison, at my suggestion, tried his methods in two cases, omitting the "Bipp," and he allows me to say that they healed as well as the others treated with the paste. What disadvantages attach to the "Bipp" method? There have been several cases of bismuth poisoning, and I have seen one of iodoform poisoning. In a certain number of the wounds, especially those which have been treated in France, the paste has been discharged in driblets, or in lumps, after the whole wound has broken down. These faults are due to a wrongful application of the method. Perhaps less

than the necessary care has been given to the thorough opening of the wound, and certainly far too much of the paste has been introduced. One writer says, "The wound must be filled with 'Bipp'"; that instruction is, of course, the very opposite of the truth. If the paste is used at all, only the thinnest smear is applied to the wound surfaces. The excellent and indubitable results of Morison's method have started once again the quest of the healing balm. All sorts of composite unguents and embalming materials have been tried with the hope of obtaining a substance having an action that may be described as a sustained push compared with the "thump" given by Dakin's fluid. A very practised surgeon, Captain Wilson Hey, has used with excellent effect a paste of which boric acid, paraffin, chalk, and brilliant green are the ingredients, and equally good results follow the use of pastes or powders containing chloramin-T and acriflavine. Many control experiments by different observers using the several pastes, or none, are still necessary before we can say if any of them, or any parts of them, are essential to an equal degree of sound healing in the wounds. Recently what may prove to be the most valuable antiseptic yet tried has been used in groups of cases under the care of a few observers. This is dichloramin T, introduced by Dr. Dakin.

Flavine Compounds.—During the last few months great interest has been aroused in the surgical world by the writings of Browning and other workers in the Bland-Sutton Institute of Pathology in praise of flavine as an antiseptic for application to infected wounds. Browning claims that flavine compounds (proflavine, acriflavine) and brilliant green exert a slowly progressive bactericidal action; in concentrations which inhibit and finally kill bacteria no harmful effect upon the tissues or upon phagocytosis is produced. It is said of the flavine compounds that their bactericidal potency is enhanced by the presence of serum; brilliant green, on the other hand, is reduced in activity by serum. The experiments of Browning are criticised by Fleming and Tanner and others. Fleming asserts that when many microbes are used in similar experiments to those of Browning the flavine must be in far greater strength than that given as the "lethal concentration," in order to effect sterilisation; that in a concentration of 1 : 2000 flavine completely inhibits leukocytic emigration; that it has, if tested over a period of twenty-four hours, a greater destructive effect on leukocytes than on bacteria. Carrel has also spoken of the weak antiseptic action of flavine, of its inefficiency under the conditions which really obtain in wounds, of the

destructive effect upon the granulations of a wound, producing necrosis, arresting cicatrisation, and increasing the dimensions of the wound if used for any length of time. We have had in Leeds, under the direction of Major Braithwaite and Lieutenant Gruner, an experience of the flavine compounds extending over many weeks and embracing a great variety of cases, and a trial of different methods of application has been made (Carrel technique, twelve-hourly dressings, etc.). The naked-eye changes are: An early reddening of the surface, a considerable diminution of the exudate, a disappearance of the fibrinous deposit, a firmer consistence of the granulations. If long continued, the flavine produces a more brilliant red tinge in the wound, a "beefy" look, and apparently all processes of healing are held in complete abeyance.

The microscopic changes are, first of all, a rapid fall in the number of organisms per field, which in several cases is apt to give place to a secondary rise about the fifth or sixth day, in the absence of any necrosis of bone or retention of clothing or missiles. Then a change is found in the character of the cells, some of which undergo cytoplasmic breakdown while others show decided phagocytic activity. Then this activity ceases to be manifest, and the bulk of the

leukocytes undergo complete necrosis. As the wound improves in appearance so do the cells become few and necrotic. It is possible, Gruner suggests, that the flavine penetrates into the cell substance and alters its metabolism, setting up necrobiosis along abnormal lines, with a resultant flooding of the tissues with abnormal products of metabolism. These arrest the multiplication of the microbes. There may be an added inhibition of the outpouring of coagulable fluids, causing the wound surface to dry up after a few days. These changes appear to be more rapid with proflavine than with acriflavine. Many of the wounds treated with these compounds have been closed by secondary suture, with results to all appearance identical with those which are found after treatment by the Carrel or Morison methods.

Such is a brief statement of the present position with regard to the treatment of war wounds. It must never be forgotten that the time element is always an important factor, and that the problem of dealing with an early contaminated wound is not identical with, indeed, may be marvellously different from, that concerned with a late infected wound. The conditions in the early hours, when the patients are at the Casualty Clearing Stations in France, are very different from those to be combated when the patient

reaches a base hospital in England after the lapse of many days or many weeks. Finally in the English army, with the channel and the long train journey interposed between the hospitals in France and those at home, a new and very difficult set of circumstances must be taken into account.

But wherever and whenever the patient is seen, the most urgent desire and the paramount concern of the surgeon is to secure closure of the wound. Whatever mode of dressing is adopted, whatever procedure, whether of physiological or of antiseptic principle, is trusted, it is the suture of the wound at the earliest opportune moment that must be the goal of every effort.

So far as our present knowledge will allow us to formulate conclusions, the following deductions may usefully be drawn:

Perfect mechanical cleansing, that is, the excision of all contaminated, infected, or dead parts, the removal of all fragments of clothing (by far the most important of all causes of continuing infection in a wound) and of all projectiles, is the supreme necessity in all cases.

In early cases, when there has been little or no loss of tissue, this may allow of immediate closure of the

wound, which will be followed by healing in the majority of cases, say in 70 per cent. or 80 per cent.

In infected early cases the mechanical exposure and cleansing may be followed by a treatment directed to the removal of the remaining infection. Physiological and antiseptic methods each have their advocates. The aim of both is to permit of the earliest prudent secondary closure of the wound. In infected late cases a thorough mechanical exposure and cleansing of the wound and the parts around will allow of secondary closure forthwith if certain antiseptic pastes are used. Experience shows that similar results have sometimes followed upon this thorough mechanical treatment of the wound without the introduction of antiseptics. A further trial in this class of cases may show that the natural defences of the tissues already awakened are ample to deal with the infections then remaining. Where large gaping wounds are left as a result of gross destruction and loss of tissue, infection is controlled and subdued without suppuration to the point of "clinical sterilisation" by the application of the Carrel-Dakin method.

It is the natural defensive powers of the body fluids and tissues, of serum and leukocytes, that are the chief agents in finally subduing the bacterial infec-

tion in a wound. Sufficient reliance does not appear to be placed upon the stupendous power the body tissues possess for controlling infection.

Finally, full emphasis must always be laid on the *paramount necessity for the complete immobility of wounded parts at all times and on all occasions.* So will one of the most powerful agencies making for reinfection be kept constantly in check.

WOUNDS OF THE KNEE-JOINT

There is probably no department of surgery in which greater changes have been wrought since the early days of the war than in that concerned with the treatment of wounds of the knee-joint. When I was first in France in November, 1914, the majority of the cases of wounds of this joint exhibited, by the time that a base hospital was reached, a grave suppurative arthritis; very often the patient was extremely ill, with a high temperature and all the evidences of a severe constitutional infection; and in a large number of cases only the most drastic procedures offered any hope that the limb might at least be saved. Too often, perhaps, we failed to remember that a man had two legs and only one life, and conservative measures were pushed to excess. In the work of the French army, as I saw it, amputation was in such circumstances often advocated and practised forthwith; and there can be no doubt, I think, that though some limbs were sacrificed that continued care might have saved, many lives were rescued that would otherwise have been jeopardised or lost.

By degrees, however, as our grasp of surgical principles grew firmer, and as transport facilities increased, cases were obtained earlier, a more direct and deliberate attack was made upon the wounds, and results began rapidly to improve. It was quickly realised that all methods of treatment of a well-established purulent arthritis were miserably inefficient, and that here, as elsewhere, every effort must be directed to such a precocious and drastic treatment of the wound as would prevent the development, never long delayed, of an infection. It was felt to be insufficient so to treat a limb as to save it only with a stiff joint; the aims must be both to save the member and to preserve the freedom of movement in the damaged articulation.

For purpose of academic description the following classes of injury may be recognised:

1. *Cases of Clean Perforating Wound of the Knee-joint by Rifle Bullet.*—There are cases in which a rifle bullet traverses the joint from side to side, often without inflicting any damage or the most trivial damage to the bone. In other cases the bullet or a shrapnel ball may have entered the joint and have lodged in the lower end of the femur, or in the upper end of the tibia. The wound or wounds inflicted may be small. They are rapidly sealed up, and pre-

sent no evidences of inflammatory reaction. The joint may or may not fill gradually with fluid during the next few days. If fluid forms and is removed, it is commonly found to be sterile. In such cases conservative methods are fully justified by the results. The joint must be perfectly immobilised and the patient retained if possible at the clearing station, so as to avoid the disturbances often inseparable from travel. Aspiration of the fluid and the injection of formalin and glycerin, formerly often practised, do not seem to insure or to hasten the recovery.

2. *Cases of Penetrating or Perforating Wounds of the Joint with a Larger Aperture of Entry or of Exit, or Both, When the Projectile is Retained in the Joint.* —All such cases must be submitted to operation. The limb, which should be immobilised at the field ambulance, is kept absolutely at rest until an *x*-ray examination is made. This is indispensable; under no circumstances may a blind exploration of the joint be made in the hope that the missile, if any, or if many, may be discovered and removed. The surgeon must know beforehand the conditions he will probably meet, and must deal with them purposefully and deftly.

The position and size of the projectile being ascer-

tained, the track of the missile must be determined. The position of the limb as it lies on the splint is, of course, hardly likely to be that which it had when the wound was inflicted.

After the whole limb has been thoroughly prepared in the usual manner, certain definite objects must be pursued. The wounds and the track of the projectile must be excised; missiles must be removed, all foreign bodies and fragments of clothing taken away, and such damaged and loosened fragments of bone sacrificed as may appear to be necessary. The technique of wound excision is the same in these injuries as in others; the damaged skin and all the bruised and lacerated track down to and including the synovial membrane are removed, if possible, in one piece. A preliminary sterilisation of the track with the actual cautery is an undoubted advantage. How, precisely, the incision is to be made will depend upon the exact circumstances. A good rule for the surgeon in all his technical responsibilities is that he should see well what he is doing and do well what he sees. These should be endeavours in the knee-joint especially.

To make a small incision, and to introduce his finger to "explore" the joint, which may mean to grope blindly and clumsily therein, is not in accord

with the needs of cases such as these. A quite adequate exposure is necessary; if this can be obtained by an enlargement of the aperture of entrance, or of exit, or of both, nothing more is required; if it cannot, then a long internal or preferably external incision is made; if these are insufficient, then the surgeon must make up his mind to a sacrifice of the ligamentum patellæ and the making of the semicircular flap fashioned in many cases of excision of the knee. By the time the patient is ready to use his limb the ligament will have united firmly and be competent to bear the strain then placed upon it. There can be no doubt, however, judging by the cases I have seen, that the functional result in all returns more slowly and always less perfectly than in those where only the lateral incisions are made. A free and full exposure of all the injured parts being then obtained, the following injunctions may be observed: to remove all dead tissue, to remove all soiled parts, to remove all foreign bodies, clothing, mud, clots, etc.

How strictly is the surgeon to interpret the rule that all projectiles must be removed? Our experience in England shows beyond dispute that—(*a*) if a projectile is embedded in the articular ends of the bones, when the bone has suffered little or no

damage beyond that necessarily inflicted by the entrance of the foreign body, it becomes encapsulated and rarely if ever gives rise to subsequent trouble; and (*b*) if a projectile, however small, remains in the knee-joint, it is an abiding source of infection and of suppurative arthritis. The most troublesome and tedious of all the cases seen at home are those in which a foreign body has been left in the joint. It is therefore a strict and necessary injunction that all projectiles should be removed at the earliest opportunity. All vessels bleeding ever so slightly in the wound are carefully secured. The wound and all parts exposed are gently wiped, and if the surgeon so desires, some form of antiseptic may be used—ether, or Dakin's solution, or saline solution. The wound is then closed by layer after layer of catgut sutures until the skin is reached. For this silkworm-gut is used.

Is drainage to be used? In the early months of the war drainage-tubes were freely, indeed almost universally, employed. Sir Anthony Bowlby, however, had often emphasized their very real disadvantages. Unlike most surgeons, I believe, he had for many years in civil practice forbidden their introduction in all cases under his care. He has now won all opinion around to his view. There can be

no longer any doubt that any form of tube introduced into the joint cavity in these early cases is productive of nothing but evil. Tubes damage the synovial membrane by their pressure, and are a potent and abiding avenue of infection. As a binding obligation, with no objections worthy of consideration, it may be asserted that tubes should never be placed within the joint. It is rare to see in the base hospitals in England a movable knee-joint when tubes have been used within the cavity. Drainage, however, may be necessary and is quite adequately secured by placing tubes "down to but not into" the joint, and by leaving a gap in the line of the sutured synovial membrane. The delicate tissue of the synovial membrane then suffers no harm, yet if effusion occurs, it finds a ready exit and easy escape to the surface. Dressings are then applied and absolute immobility secured for eight or ten days by a splint.

There are cases, probably between 10 and 15 per cent. of the total number, treated upon these lines, in which an effusion into the knee-joint, larger or smaller in quantity, associated with an elevation of temperature, may occur, generally after the fifth or sixth day.

What is then to be done? This question is to be answered by the bacteriologist and the surgeon work-

ing together. An examination of the fluid discharged from the tube, or removed by aspiration of the joint, must be made forthwith. If any organisms but the streptococcus or staphylococcus are found, there is no need as yet for anxiety. In quite a number of the cases the fluid will prove to be sterile and will leak away by slow degrees through the aperture prudently left in the synovial membrane. Day by day the temperature will fall and the knee assume once again its normal size, and all will at last go well. If, however, the staphylococcus is found, the joint must be watched almost from hour to hour. If fluid is leaking away slowly and if the temperature tends to fall, and if the patient remains comfortable, then expectant methods may safely be continued. In the great majority of such cases all anger will subside and the infection will be subdued by the patient's own efforts. Such cases help one to realise the strength of the defensive power that the knee-joint is capable of exercising. When, however, the streptococcus is present, active and timely interference is necessary. The joint must be freely opened by long lateral incisions or by semicircular incisions dividing the patellar ligament. The synovial membrane must be stitched to the skin, and the Carrel-Dakin method adopted. If the infection is of a still

graver or more hostile kind, excision of the joint or even amputation may be imperatively necessary.

There are few types of cases, if, indeed, there are any, which give such genuine gratification to the surgeon practising in England as those treated in France by methods similar to those described. A very large number have now been received into our base hospitals in which, a month or six weeks after an injury that two or three years ago would have meant permanent disablement of the joint as the best attainable result, all movements of the knee are free and unimpeded and attended by no pain whatever. In no circumstances do we realise with such certainty and satisfaction the remarkable scientific advances made by our colleagues working with the army in France.

3. *Cases of Perforating or Penetrating Wounds of the Joint with Intra-articular Fracture.*—This condition is a degree more serious than that in which the missile has cleanly entered and become firmly embedded in the end of the femur or the tibia. There is here a shivering of the articular ends, with many irregular lines of fracture. In the midst of a soft mass of crushed bone the projectile may be lying. All such cases must be dealt with ruthlessly. There must be adequate exposure by one or other of the

incisions before mentioned; all dead, severely damaged, or entirely loose fragments of bone taken away; the curette or the bone forceps being used to get rid of all bone which is beyond hope of recovery. As a rule, the distinction between sound and doomed bone is easily made. The articular cartilage is, however, always dealt with most sparingly. The future integrity of the joint movements depends upon the preservation of every undamaged scrap of this structure.

It will often be found that an injury which before free exposure has appeared trivial is seen, when the joint is opened up, to be very extensive and to require a careful and long-continued toilet before all parts are cleansed and removed. It may be necessary once or twice to change instruments, gloves, or towels, in the due observance of the strict aseptic ritual always necessary. When all parts are cleaned, the most perfect hæmostasis is secured and the wound then closed.

In many cases in England we have used Morison's paste (Bipp) to smear over the rough osseous surfaces which remain or over a bruised or inflamed synovial membrane. I have seen several cases of severe infection of the knee treated by Mr. Morison himself, and have been surprised some weeks later

to see what a remarkable degree of functional restoration has been obtained. It is in these severer forms of injury to the knee-joint that we have by degrees been brought to realise that our old timidity toward this joint is quite needless. It is no exaggeration to say that with proper care the knee can protect itself from infection almost as well, if not quite as well, as the peritoneum. Our fear of infections within the joint was due to an ignorance of the methods of treatment of them. Most surgeons dealing with even a mild infection, and probably all surgeons dealing with anything approaching a grave infection, relied upon drains introduced into the cavity of the joint to rid the parts of inflammatory products. We know now that nothing but harm comes from a drainage-tube placed into the joint. If drainage is necessary, it is secured by tubes down to the synovial membrane but not within it, by suturing the synovial membrane to the skin, or by adopting, as Mayo Robson suggests, a special posture of the limb.

4. *Cases of Injury to the Knee-joint, with Extensive Fracture of the Articular Ends of the Bones.*—The practice to be followed in such cases will depend upon the position and extent of the injury, the number and localisation of the projectiles, and the degree

of infection. If there is extensive fracture without loss of tissue, it is probable that an attempt to save the knee will be worth while; that even if ankylosis results, the firmness and strength of the limb will be adequate to most purposes. When, however, there is extensive localised loss, as, for example, when one condyle of the femur is blown completely away, then a formal resection of the knee-joint forthwith is probably the best course. In such a case, even if complete healing takes place, the functional utility of the limb is greatly hindered by those deformities which inevitably follow. As much of the femur must be spared, in making the resection, as can with safety be left; the upper end of the tibia, if intact, must have only the merest shaving of the articular cartilage excised, enough, that is, to allow a bony ankylosis to take place. The amount of the two bones that can be removed without serious disablement is remarkable. I have had one patient whose leg was a trifle over four inches shorter than the other who walked with vigour and not inelegantly. A part both of the femur and of the tibia had been destroyed by a shell fire.

In cases included in this group where infection has obtained a hold the method of excision introduced

by Colonel Fullerton may be practised. Instead of bringing the opposing ends of the femur and the tibia together, means are taken by extension to keep them apart. A wide gap then is left which may be filled lightly with gauze and the Carrel-Dakin method of treatment adopted. When the wound has reached the stage of "clinical sterilisation," the bones may be fitted together and the limb fixed in a splint.

In still more than severe types of injury amputation of the thigh is performed without delay. This counsel is especially urgent when the great vessels also are injured, when laceration of the soft parts is extensive, and when infection, especially with the bacillus of gas gangrene, is evident.

CONCLUSIONS

1. In all cases of wounds of the knee-joint the limb should be fixed immovably upon a splint at the earliest possible moment, and until circumstances and surroundings permit of a complete operation.

2. At the Casualty Clearing Station, or other operating centre, an *x*-ray examination is made in all cases. The whole limb is then prepared for operation.

3. The following are the essential features in all operations: excision of the wounds and of the track

of the projectile after preliminary sterilisation by the cautery or otherwise; a free exposure of the joint, either by enlarging existing incisions or by long internal or external incisions or by the formation of a flap by division of the patellar ligament.

4. All foreign bodies must be removed from the joint. Even the smallest piece of clothing or of metal may be the nidus of a continuing infection.

5. The wounds are closed in layers by catgut sutures. Drainage is secured by leaving a gap in the line of suture of the synovial membrane, or by leaving a tube close "down to but not into" the joint.

6. Drainage-tubes are never placed within the joint cavity. They do not drain the joint; they are harmful in their effects upon the delicate synovial membrane, and they are often a channel by means of which infection is conducted to the joint.

7. In cases of severe infection of the joint by staphylococcus, or especially by the streptococcus, the wounds must be reopened, the synovial membrane stitched to the skin, free drainage of the joint secured, and the Carrel-Dakin or other method of progressive sterilisation of the wound adopted. In more severe cases, with an infection rapidly gaining ground, excision of the joint may be necessary.

8. In cases of severe comminution of the articular ends with much loss of substance (the whole of one condyle, for example) a resection of the joint is performed forthwith.

9. In severe and extensive wounds with heavy infection the method of resection with wide, temporary separation of the ends of the bones (Fullerton) should be practised.

10. In cases of very extensive damage, especially with infection, amputation is desirable.

The following record, made by Colonel Gilbert Barling, C. B., of the work done at a group of base hospitals in France, though many months old, may still be quoted with interest:

1.	Total cases of injury to knee operated on	845
2.	With bone injury	438
3.	Without bone injury	407
4.	Wound excised and closed	322
5.	Cases under (4) requiring further operation	82 = 25.5 per cent.
6.	Wound excised and packed	336
7.	Cases under (6) requiring further operation	128 = 38.4 "
8.	Excision of knee	42
9.	Arthrectomy, partial or complete	15
10.	Excisions or arthrectomies amputated	13 = 22.8 "
11.	Deaths after excision or arthrectomy	13 = 22.8 "
12.	Amputation without excision	151

13. Deaths under class 12 . . . . . 49 = 32.4 per cent.
14. Total amputations . . . . . 164 = 19.4 "
15. Total mortality . . . . . 72 = 8.5 "

NOTE.—One hospital with a large number of cases was unable to separate the cases under items 4 and 6.

ON INJURIES TO THE PERIPHERAL NERVES AND THEIR TREATMENT

In the preparation of this paper I have received valuable help from my colleagues on the staff of the Second Northern General Hospital, Leeds, Captain Burrow, Captain Daw, Captain Richardson, and Dr. Cuthbert Morton.

NATURE OF INJURIES

The lesions of nerve-trunks as the result of wounds inflicted in war may be of diverse forms:

I

In the majority of cases the nerve-trunk has not sustained a primary injury. It may be exposed in greater or less degree in a wound of the soft parts with or without fracture. If the wounds are gravely infected and suppuration occurs with, perhaps, necrosis of one or of many fragments of bone, the process of healing may be long delayed, and the cicatricial tissue which results will be of exceeding density. The nerve then may come to lie in the midst of a fibrous mass which, undergoing progressive contraction, presses more and more firmly upon the delicate and tender tissue of the nerve. The nerve-trunk is

strangled, bereft of its due supply of blood, and becomes in consequence functionless. It is impossible before operation to decide in the severer cases whether such a nerve has or has not been completely divided.

II

The nerve-fibres may not have been directly, or they may have been only very trivially, implicated, but the projectile may have passed so near the nerve-trunk as to have opened its sheath. The nerve then becomes adherent to the track of the missile, and a mass of fibrous tissue is found firmly welded on to its lateral aspect. Or the projectile, in this case a rifle or machine-gun bullet, may at that period of its flight when it has become steady have cleaved through the trunk of a nerve, separating the fibres and severing few or none. Hæmorrhage within the sheath occurs, and a fibrous mass develops in the centre of the nerve, causing it to assume a fusiform appearance. There is, then, a *central neuroma*.

III

The nerve may have been partly severed, say in half its diameter, by a projectile or a fragment of bone. The gap in the nerve is soon filled up by fibrous tissue, which extends widely upward and downward

and away from the side of the nerve, so that a hard fibrous *lateral neuroma* is found.

IV

The nerve may be completely severed. In such a case a gap of greater or less length is found between the divided ends. Bridging this interval there may be a connecting strand of fibrous tissue, or a blurred mass of scar material in which both cut ends are lost. In some cases the nerve may appear hard and swollen, and as though its fibres were continuous; but careful dissection will show that there is complete division.

When the nerve has been cut completely across, the upper divided end is soon found to present a characteristic bulbous appearance. On section this is seen to consist partly of fibrous tissue and partly of nerve tissue. From the upper end of any divided nerve the axis-cylinders grow downward tirelessly, each one searching out diligently but blindly the lower end to which it seeks to unite. When the quest fails in one direction and an uncongenial tissue is met, the axis-cylinder turns in another direction, searching there fruitlessly again, and so twists itself in ceaseless contortion until a tumour—a *terminal neuroma*—is formed.

The fibrous mass, often of extreme density, which goes to the making of the bulbous end is probably the

reply of tissues to the contact of exposed nerve-fibres with them. The peripheral nerves are intruders among the other tissues of a limb, reaching them by a process of invasion from without. The contact of these nerve-fibres with any other tissue is prevented by their closure within a sheath whose function appears to be that of an insulator. The end organs of the sensory nerves may indeed be, as W. Trotter suggests, a special mechanism for isolating the nerve-fibres, protecting them from actual contact with the tissues. Whenever the nervous system is injured, by accident or design, as in the operations of trephining and laminectomy, there is always a hasty and adequate attempt to isolate the parts again. There is an intolerance of the tissues for contact with nerve matter or, conversely, of these with other tissues.

Gosset says that the axis-cylinder is very unintelligent. I am not sure that its search for the distal end is stupid because it is unsuccessful. The search is zealous enough, but the axis-cylinder shrinks from ignoble contact with a baser tissue, and turns aside to seek elsewhere.

The lowered severed end becomes thickly covered with a fibrous cap which forms a barrier impenetrable by the axis-cylinders seeking so earnestly to find their way along the distal nerve.

1. THE NERVES INJURED; RELATIVE FREQUENCY

The relative frequency of affected nerves has in our experience been as follows:

	Per Cent.
Musculospiral	25
Ulnar	24
Median	14
Sciatic	12
External popliteal	12
Internal popliteal	1
Upper portion of the brachial plexus	4
Lower portion of the brachial plexus (cords)	7
Anterior crural	1

This corresponds fairly accurately to the experience recorded by Gosset and by Tinel.

2. DIAGNOSIS

The following points in the clinical histories are investigated:

Date of injury.
Nature of projectile.
Position of patient at moment of injury.
Immediate effects.
After-history (including history of operations performed).
Physical examination consists in—

A. *Inspection of the limb to note—*
1. Attitude, contractures (claw hand, etc.).
2. Position of wounds and scars.

B. *Testing of the Efferent Impulses.*

1. Motor weakness for paralysis, each muscle and each muscle group tested separately.
2. Trophic and vasomotor disturbances. Non-shedding of epidermis, "glossy skin," ulcers, changes in nails, etc.
3. Changes in deep tissues, for example, muscular atrophy, fibrillation, bone decalcification, etc.

C. *Testing of the Afferent Impulses.*

1. Pain, its character, distribution, relation to hot and cold applications or weather.
2. Loss of cutaneous sensibility, tested by standardized stimuli of special instruments so that results are strictly comparable.
   Light touch.
   Localisation of spot touched.
   Tactile discrimination (pressure, texture, etc.).
   Stereognostic sense (size and shape of three dimensions); appreciation of compass points applied simultaneously.
   Thermal stimuli (hot and cold test-tubes).
   Painful stimuli (pinprick controlled by standardized spring).
   Roughness (Graham Brown æsthesiometer).
3. Deep sensibility.
   Pressure pain.
   Vibration sense in bones.
   Joint and muscle sense, etc.

Electrodiagnosis

The reactions to the interrupted current are tested by shocks from an induction coil, the electrode being placed upon the "motor point" of each muscle in turn. The current from a secondary coil is always used.

A positive reaction to faradism is regarded as a contraindication to operation, but failure to respond gives no definite information, for voluntary movement may return, after nerve injury, before the faradic response.

The muscles are next investigated by a constant current. "Polar changes" have been found to be of minor value; they may vary with the local circulatory changes following massage, etc. The character of the contraction is of much more importance. A brisk twitch indicates the probable presence of some conducting nerve-fibres in the muscle tested, while a slow "vermicular" response is usually associated with a complete interruption of nerve-fibres.

The nerve muscle is next examined by means of a condenser discharge. The method depends upon the fact that a condenser discharge through a constant resistance gives a current which varies in duration according to the capacity of the condenser used.

The more severe the damage to the nerve, the

greater will be the capacity of the condenser required to excite it. Or, in other words, the longer the duration of the current, the more chance is there of obtaining a response in such a nerve muscle. The whole advantage of the condenser method is that a definite measurement of current or condenser used may be noted, and future progress may be accurately followed.

The condenser method is chiefly used in cases where operation is deferred because some function is found to be present in a given injured nerve. (The work done recently by E. D. Adrian and others shows that the condenser is disappointing in practice; but it nevertheless gives useful information in recording progress.)

Complete absence both of faradic and galvanic response is an indication for early operation. The cases which require careful and repeated examinations are those where there is pressure on the nerve-trunk by a contracting scar. In some nerve-trunks there is little damage to some of the fibres, with total loss in others. Operation must not be deferred too long in these cases, because the fibres with complete reaction of degeneration may never recover on account of a dense scar tissue formation at the site of injury. In other words, the presence of a degree of volun-

tary power in some individual muscles of a group supplied by a damaged nerve is no sure criterion that the paralysed muscles will recover without operation.

It is most important that nerve injuries should be reëxamined at frequent intervals and carefully detailed records of motor power, sensory changes, and electrical reactions kept. In this way treatment may be modified according to progress.

In operations upon nerves where a diagnosis of total loss in some fibres only has been made it is our practice to test the exposed nerve both above and below the site of injury at the time of operation.

For this examination special sterilisable electrodes and long connecting cords which can be boiled are used. The nerve is gently lifted upon two small glass hooks and a very weak faradic current employed.

The most accurate anatomical arrangement of fibres may be noted by this means and the knowledge used to secure perfect adaptation in nerve suture. The diagnosis is often completed during a period in which massage, baths, and electrical treatment are employed to improve the local circulation, and splint treatment adopted to relax affected muscle groups and to overcome contractures. The distinction be-

tween anatomical and physiological division is not made before operation.

DIFFICULTIES IN DIAGNOSIS

The main difficulties encountered in arriving at an exact diagnosis are in cases where there are:

Wasting and stiffness from disuse.
Circulatory disturbances.
Contractures.
Destruction or adhesion of muscle and tendon.

Operation is decided upon in the following circumstances:

1. In cases of complete division.
2. In cases of incomplete division, where progress is arrested.
3. Where there is severe neuralgic pain, "causalgia."

Operation is deferred—

1. For one month after the closure of the wound where soft parts only are injured.
2. For two or three months after complete closure of the wound where bone has been involved.
3. Definitely so long as progressive signs of recovery in nerve functions continued.

The suture of the nerve may have to be delayed until unsatisfactory joint conditions are improved.

Contractures of the knee, for example, should be corrected before the sciatic nerve is sutured, otherwise the nerve would be in danger of rupture if the deformity were subsequently rectified.

In other cases the nerve may be sutured and the joint dealt with at the same period and subsequently.

It is of the first importance to start active measures to prevent or remove stiffness and deformity in the parts supplied by a wounded nerve. This can often be done for many weeks before it is possible to repair the nerve. It is not sufficiently realised that a nerve to be of use after suture must act upon live and supple tissue. Joints and muscles must be kept ready for the nerve impulse which some day will come to them again.

OPERATIONS

When the diagnosis of a nerve lesion requiring operation has been made, the earliest prudent occasion must be chosen for operation. In both the French and British armies nowadays the suture of a divided nerve is performed in those most advanced operating centres where the first deliberate toilet of the wound is possible. It is realised, of course, that very often a complete union between the severed ends cannot result, but even if the operation prove eventually to be a complete failure, the subsequent

operative procedures are certainly easier, and it is a satisfactory thought that a chance has been given for healing to take place.

In the great majority of nerve lesions dealt with up to recent times the wound inflicted by the projectile has suppurated. We have learned by bitter experience in this war what this means. It means that the bacterial flora in such a wound are numerous, and potentially, at least, of great malignancy. It means that even a simple operation upon a wound which still discharges pus may arouse a flaming infection and be a cause of tetanus or gas gangrene. Mere passive movement of a joint grown stiff by inactivity may bring about an attack of tetanus even though the adjacent wound has healed. In many cases an injury to bone may have been inflicted at the same moment as the division of the nerve; this is, of course, frequently the case when the musculospiral nerve is implicated. Many loose pieces of bone may remain as sequestra in the wound and may need removal or may escape spontaneously from time to time. In all such cases operation upon the nerve must be deferred until the wound has been soundly healed for some weeks; no rule is more binding upon the surgeon than that. During this period, which may be protracted, the most diligent attention must

be given to the limb, especially to those parts, muscles and joints, distal to the injury. The paralysed muscles must be kept in a position of relaxation. This may be easy, as in those cases where the musculospiral nerve is divided; it is often difficult, as in cases of injury to the median nerve; it is sometimes impossible, as in dual or triple lesions of nerve-trunks. But, difficult or easy, the best possible must be done, for the final functional result in respect of quality and of rapidity depends in no small degree upon the early care of the parts deprived of their nerve supply.

Special and unremitting attention is given to the joints, which must always be kept supple. It is remarkable how quickly the fingers, for example, become so stiff that forced movement is an agony. Every day, many times a day, all the paralysed parts must be freely moved to their full range, and the patient must be instructed to attend to this matter unceasingly. The most perfect nerve healing is robbed of its value if, through long disuse, the muscles whose innervation is restored have lost their power to act, and if the joints are so firmly ankylosed that even passive movement cannot bend them fully. The value of these preliminary and preparatory measures cannot be overestimated.

When the operation actually takes place it is important to observe certain essentials to success. There must be the most perfect and scrupulous asepsis and the most gentle handling. The finger should never be placed in the wound. All dissections should be carried out deftly and neatly with a very sharp knife, in the "feather edge" method of Crile; the most diligent care must be taken never to bruise the nerve by seizing it, however gently, in forceps. The nerve must never be twisted, or torn or stretched, or unduly separated from its bed. Other structures must be dissected from the nerve: the nerve must not be dissected from them. The nerve must not be stripped bare for too long a distance, otherwise it will be devascularised, and recuperative processes will be slow or absent. The wound as a whole, and the nerve in particular, must not be allowed to dry or to be chilled. The most dainty and precise movements are necessary throughout, and every bleeding point must be thoroughly secured. There are, of course, the observances that go to make up the ritual of every well-trained surgeon; their strict acceptance is more necessary here than in almost any other operation, if the most rapid and the most flawless recovery is to be made certain.

As a rule, a tourniquet is undesirable, for two rea-

sons. It is possible to harm the nerve, or other nerves in the limb, if the rubber band is applied too tightly, and for the long period sometimes necessary in this procedure; and when the operation is complete and the tourniquet removed, there will probably be an escape of blood into the wound—a thing in these cases most undesirable. In these wounds not infrequently there is a good deal of young fibrous tissue, from which free oozing may occur in the period of hyperæmia which follows removal of a tourniquet.

The incision is designed to fall on the skin at some distance from the original wound if possible; very often a flap will occur from the making of a curved incision. The planning of the incision gives scope for one's knowledge of anatomy; it is so arranged that no small nerves are wounded. Major Jamieson has shown that when the median nerve is injured in the forearm it may sometimes be more thoroughly and successfully dealt with from the outer instead of from the inner side of the flexor carpi radialis. So, too, when the musculospiral nerve has been injured high up on the outer side of the forearm, Dr. Cuthbert Morton suggests that instead of cutting through the outer head of the triceps it should be reflected complete from the humerus. Not only does this cause less damage to the muscle tissue, but it

also exposes the nerve and its branches, as well as the profunda artery, to a very high level without undue risk.

The nerve-trunk is sought above and below the point of severance, and is traced downward and upward to the gap. Swift, neat little cuts with a very sharp scalpel damage the tissue to the smallest possible degree. The surgeon must avoid contact of his fingers with the wound: it is clumsy and inartistic to prod about among muscles in the hope of feeling the nerve. It is his business to know before he begins these operations exactly where the nerve lies, and he should always be able to cut directly down on it. When the injured part of the nerve is exposed, it is usual to find a bridge of fibrous tissue between the ends, the proximal end being often very turgid and bulbous. If the gap between the refreshed ends of the nerve is likely to be wide, now is the time for stretching the nerve, so as to lessen the interval as much as possible. This is done with infinite gentleness and care by seizing the fibrous band between the ends and drawing steadily upward and downward, always remembering to make the pull in the line of the nerve-trunk and to avoid twisting. The fibrous band is now split longitudinally, and then its ends are divided above in one direction, below in the

other, so that to each cut end of nerve a fibrous tag is attached, by means of which the nerve-ends can be drawn together. Progressive transverse cuts are now made into the nerve-ends until on the cross-section nothing but nerve-fibres are seen. Every tiniest particle of fibrous tissue must be removed or the operation will fail. The axis-cylinders coming from above must have free entry into the nerve below, otherwise in their downward development they will lose their way, and restoration of the nerve function will not take place. When the nerve-ends are duly prepared, they are brought into apposition with the greatest care. A series of very fine catgut sutures holding only the nerve-sheath are inserted at intervals around the circumference of the nerve. A suture is never passed through the substance of the nerve itself. In uniting the nerve-ends it is of the first importance to avoid axial rotation. We know now that there is a differentiation of function within each nerve, and it is, therefore, strictly necessary to unite corresponding bundles of fibres. A nerve does not act as a whole, but consists of a multitude of strands each with its proper and restricted function. Unless nerve bundles which were originally continuous are brought accurately together by suture, the nerve is compelled to rearrange the functions of its several

parts. This it can and no doubt frequently has to do. An examination of many cases shows, however, that a perfect and flawless recovery after a nerve suture is unusual, and it is at least a tenable belief that this inadequacy or delay in recovery is due to a want of recognition by the surgeon of all that is needed in the technical part of the operation. My colleagues on the staff of the Second Northern General Hospital in Leeds are obtaining results which in rapidity and completeness would have been thought impossible before the war.

There is rarely any difficulty in obtaining accuracy of apposition without tension. If, however, the nerve-ends cannot readily be brought together, various procedures may be adopted to shorten the course of the nerve. The nerve may be dislocated from its bed and laid in a new and shorter line. The ulnar nerve, for example, may be brought to the front of the inner condyle. Or flexion of the limb may be enough to allow of easy approximation. In the case of the median nerve divided low in the forearm, flexion of the wrist will give an inch or more additional reach. In other cases the limb may be shortened by removing an inch or two of bone. It is desirable to avoid a subcutaneous course in all transferences to new positions. The nerve after suture

should be brought to lie in a bed of healthy tissue. It must be placed between muscles, and away from all contact with new connective tissue, which will adhere to it and hinder its union, or cripple its subsequent action.

It has been the fashion with many surgeons to surround the sutured nerve with some material supposed to have protective virtues. A piece of a vein—the saphenous, for example—is threaded over the upper cut end of the nerve before suture, and after these ends are approximated the vein is drawn downward and made to surround the line of suture. In other cases a piece of fat dissected from near the wound, or from another part, is wrapped around the nerve, fat being supposed to be capable of insulating the nerve in its new position, or a layer of fascia may be used, or a piece of Cargile membrane. The value of all such methods is open to serious question; it is certain that they are sometimes harmful: it is doubtful if they ever help. They prevent access of blood to the nerve by new channels; they cause adhesions and compression of the nerve, and at times they are discharged from the wound almost unaltered. It is better to avoid such membranes, and to be content with insuring that the nerve is laid along the path of uninjured tissues. Where end-to-end suture is im-

possible, a variety of other procedures may be attempted. A nerve graft, taken from a neighbouring cutaneous nerve—from the radial, the internal cutaneous of the thigh, or an intercostal nerve—may be used. Experience on the human subject has not yet enabled me to determine the value of this procedure. In experimental work it answers well, but I have rarely, if ever, seen a result which could be claimed as satisfactory. Colonel Mayo-Robson has had one of the very few successful cases.* Nerve anastomosis has been tried in a number of cases. The divided ends of a nerve are implanted into the side of a near-lying nerve, the ulnar into the median, for example. This has been done both with and without section of the nerve-fibres of the intact nerve. All such procedures are worthless, and cannot be too strongly condemned. I have never seen any good come of them; indeed, nothing but harm could conceivably result from section of a healthy nerve. And if it is allowed, as it must be, that a nerve consists of many separate strands, each with its own special and exclusive function, it is certain that permanent damage is inflicted by this method. There is no justification for this procedure nowadays, and it should be cast out among forgotten things. Lengthening of the nerve by turn-

* British Medical Journal, 1917, i, p. 117.

ing down a strand from the upper divided end and the bridging of the gap by strands of catgut, are methods with nothing whatever to recommend and everything to discredit them.

Happily the resources of surgery are not at an end in all cases where union of divided nerves is impossible. Tendon transplantation, especially in the case of the musculospiral nerve and the posterior interosseous, gives results which, in point of function, are almost as good as those which come from nerve suture, and in point of time are much quicker. It is chiefly in the musculospiral nerve that large gaps are found, a piece of the nerve having been blown completely away. In such cases tendon transplantation gives excellent and speedy results. When the posterior interosseous nerve is wounded it is not worth while attempting to suture the nerve. The results in such cases are slow, and not always perfect.

In those cases where the nerve is partly divided, strands of intact fibres still remaining, the severed fibres are united in the same careful way, and the normal strand of the nerve bent upon itself, so as to allow easy approximation of the cut portions of the nerve. In perhaps the majority of operations upon nerves there is no division of fibres, but a length of the nerve is embedded in dense fibrous tissue. These

cases give most excellent results. The fibrous tissue which so intimately surrounds the nerve is dissected away little by little. The nerve when first freed is seen to be white and shrunken; but within a few minutes it expands and takes on its normal colour. I had several cases of this kind in the Boer war, and the results at this long interval are perfect. It is in these cases that advantage may sometimes be taken of the method of fat transplantation or of nerve dislocation.

AFTER-TREATMENT

1. Postural

In cases where flexion of a joint has been necessary to allow approximation of the cut ends of nerves, the position is maintained for a period of six weeks. By this time union of the severed ends is probably well advanced. Extension by slow and most cautious degrees is then begun. If the knee has been flexed to allow the sciatic nerve to be united, the patient can walk with a boot and leg irons, keeping the position unaltered for, say, two months. Wherever possible a splint is applied which produces a "relaxation position." In the case of the median and ulnar this is difficult, and is best secured by molding a "ball splint" to the hand of the patient. Every such splint must be made for the individual. In the case of the

musculospiral it is very simple. The "cock-up" splint designed by Colonel Sir Robert Jones is excellent if the lesion of the nerve is below the branch to the supinators. It maintains hyperextension of the wrist, and, reaching only to the heads of the metacarpal bone, it allows a forward bend of the metacarpophalangeal articulations. The thumb lies forward and a little inward, so that the position of the whole hand is very much that assumed when a bottle is grasped. If the lesion is above the nerve to the supinator brevis, it is essential that this muscle also should be relaxed. For this purpose Dr. Cuthbert Morton has devised a splint which retains the forearm and hand in supination while the wrist is fully extended, the fingers being at the same time kept in the bottle-grasping position.

Similarly in cases of injury to the external popliteal nerve relaxation of the corresponding muscles may be secured by the boot which has been introduced by Dr. Cuthbert Morton in order to allow the patient to walk about with the foot in permanent dorsiflexion.

2. Massage and Electrical Treatment

These measures are restarted about two weeks after operation with all due precautions and safeguards. If

a splint has been applied to secure the "relaxation position," it must not be removed. Indeed, not for one moment at any time must paralysed muscles be stretched. An overstretching of a few minutes may call for diligent treatment of many weeks before the harm is undone. If a splint needs removal for purposes of cleanliness, the patient must be instructed beforehand to keep the limb in the exact position required. In the case of musculospiral palsies the hand drops into the correct position if the flexor surface of the forearm is *upward.*

RESULTS

Our records are as yet necessarily incomplete. Recovery in the case of the musculospiral has begun within nine weeks; in the case of the ulnar within three and a half months; in the case of the median in about four to five months. In one case of division of the inner cord of the brachial plexus recovery in all anæsthetic areas and a degree of recovery in all muscles occurred within five months. Recovery in the case of the sciatic nerve is slower. Something depends, it is sometimes said, upon the length of time elapsing between division of the nerve and its suture. My colleague, Captain Richardson, has, however, united the ends of an ulnar nerve cut across

fifteen years before and signs of returning function were seen in about four months. The duration of the disability is, therefore, no bar to successful repair of the nerve.

The functions return usually in the following order:

1. Trophic and vasomotor function.
2. Deep sensibility.
3. Tactile discrimination and localization.
4. Motor power.
5. Cotton-wool sensation.

Perfect restoration of function has been most nearly approached in the case of the musculospiral nerve. In other nerves with more complex distribution perfect recovery will depend upon a recognition of the functional localization within the nerve-trunk, in addition to the most scrupulous observance of all those technical details without which there will always be something less than perfection.

In the diagnosis and treatment of an organic lesion of a nerve it should never be forgotten that there may be superadded a functional disability. It is advisable at every stage to get rid of the functional in order properly to appreciate the organic. This is particularly important when the organic lesion is well on the way to recovery. Thus, in a recovering lesion of the inner cord of the brachial plexus it may be im-

possible for the fingers to be flexed until reëducation has trained the laggard muscles into obeying orders from headquarters.

SUMMARY

The following summary may be given of our experience up to the present time:

1. The earliest examination should be made of all wounds in which division of a nerve-trunk is probable. If at the Casualty Clearing Station such a lesion is found, end-to-end suture should be adopted forthwith. This is more likely to be possible in cases where primary suture of the wound, after excision, is found practicable.

2. If secondary suture of the wounds, after the Carrel-Dakin method has been practised, is to be undertaken, the union of divided nerves should be secured at the same time.

3. If these methods have been attempted and have failed, they do not prejudice the later union of the nerve. On the contrary, they probably insure that an easier and more satisfactory operation can then be practised.

4. Throughout the whole period before late nerve suture is attempted the strictest attention must be paid to the relaxation and nutrition of all paralysed

muscles, to the maintenance of suppleness in all joints moved by these muscles, and to the preservation of the integrity of the skin.

5. Operations upon nerve-trunks demand the most scrupulous observance of the ritual of asepsis. There must be the greatest gentleness of manipulation; the nerve must not be injured by instruments or by the surgeon's finger; it must not be separated from its sheath or disturbed overmuch from its bed; it must not be chilled or allowed to dry. All sutures must be of fine catgut, and introduced with most punctilious accuracy. Axial rotation of the nerve must be avoided. The cut ends of the nerve before approximation must show clearly the fibres of which the trunk consists.

6. Nerve-grafting is of little or no value; nerve anastomosis is to be sharply condemned; the turning down of flaps from the nerve to bridge a wide gap is useless.

7. Tendon transplantation is of great value in cases where nerve suture is impossible, or has given a result not entirely satisfactory.

GUNSHOT WOUNDS OF THE LUNGS AND PLEURA

The mortality of chest wounds in all zones of the army is extremely difficult to ascertain with anything approaching accuracy. Pierre Duval, whose work on the surgery of the lungs during this war has been characterised by originality, insight, prudent courage, and great technical success, has gathered together the records from many points of the French army. Of a total of 3455 cases, there were 688 deaths—roughly, a mortality of 20 per cent. But the mortality differs, as may well be imagined, at various parts of the line of communications. At the aid posts it is terrible—not less, it is asserted, than 25 to 30 per cent. At the ambulance chirurgical automobile, or Casualty Clearing Stations, the mortality is about 18 to 20 per cent. In the base hospitals the death-rate is about 10 per cent. There is, it will be seen, a progressive diminution in mortality from the front to the base. P. Duval scrutinized these figures in the following remarkable way:

At the aid post, where the mortality is 25 per cent.,

there will remain alive, of 100 patients, 75. At the ambulance, of these 75, 20 per cent. will die and there will remain 60 patients. At the base of these 60, 10 per cent. will die, so that finally 54 cases will survive.

Two series of cases falling under individual observation may be quoted. Gregoire records a total of 404 cases of chest wounds, pure and simple, with 47 deaths—a death-rate of 11.7 per cent. Of these, 57 patients were operated upon for empyema, with resection of the rib and drainage; 26 died—a mortality of 45 per cent.

Depage, at his well-known hospital at La Panne, which combines the functions of Field ambulance, Casualty Clearing Station, and Base Hospital, receiving patients a few hours after injury and retaining them as long as is necessary, records 320 cases of pure chest injury with 59 deaths, that is, 18.4 per cent. Within the first twenty-four hours 9.4 per cent. of cases died, chiefly from hæmorrhage. In the later stages 10 per cent. of the survivors died, chiefly from sepsis.

Elliott* estimates the mortality of chest wounds in the British army in France, at the field ambulances, and Casualty Clearing Stations at from 20 per cent.

*Lancet, 1917, ii, 371.

to 25 per cent., of which 10 per cent. to 15 per cent. are the early result of shock and hæmorrhage, and of which 10 per cent. die of sepsis. The mortality on the lines of communication is about 5 per cent.; all these deaths are from sepsis. The mortality of cases reaching England is small.

All observers are agreed that there is a difference in the mortality according to the nature of the projectile inflicting the injury. If a rifle bullet causes the wound, the condition resulting is either very serious if a large vessel is struck, or very benign if the lung tissue is traversed without serious vascular injury. Wounds from high explosive shell, the fragment causing the wound being irregular and jagged, the pieces of clothing or of skin being driven deeply in, are always serious by reason of the infection that was so prone to follow. Rouvihois, in 102 cases, found the following:

In 60 cases where the projectile was retained there were 27 deaths; in 26 of these the wound was caused by shell, in 1 case by rifle bullet. In 42 cases of perforating wounds there were 10 deaths; in 9 of these the wound was caused by shell and 1 by rifle bullet. These are truly remarkable comments upon the influence of the projectile in determining the mortality.

Death occurs chiefly from two causes: from hæmorrhage and from sepsis. Hæmorrhage is fatal early—generally within the first twenty-four or forty-eight hours. Sepsis proves fatal at a later stage—generally from the seventh day onward. The most fatal cases are those where there is a gaping wound of the chest, so that the lung is freely exposed. The mortality in cases where the chest-wall is closed behind the projectile is rather less than one-half of that which results when there is an open wound. Captain H. Henry, in 100 postmortem examinations made upon patients with chest wounds who reached a base hospital in France, found that the great majority of deaths were due to septic infection. Only four patients died from hæmorrhage, and in three of these the hæmorrhage was secondary in character and was induced by sepsis.

PATHOLOGICAL ANATOMY

The injuries inflicted by a projectile entering the chest may be considered in relation to their effects upon:

(*a*) The chest-wall.

(*b*) The injured lung.

(*c*) The opposite lung.

The Chest-wall.—The damage done to the chest-

wall may be of the most diverse forms. There may be a clean penetration of the thorax from front to back, the projectile, in this case a rifle bullet, cleaving a way through all the tissues it meets here, precisely as it does when the thigh or the soft parts anywhere are pierced. In many of these cases, however, and in a still larger number when there is a shell-wound, there is a fracture of one or more of the ribs or of the scapula. Fragments of bone, tiny spicules, or larger pieces are carried into the chest, and at a later operation may be recognised and removed either from the lung itself or from the pleural cavity, especially in the cul-de-sac above the diaphragm. The same results follow this scattering of the bone into the lung as occur when there is a compound fracture of the long bones in the limbs. Each bony sequestrum becomes itself a projectile driven with force into the tissues, and carrying with it a capacity for infection, and inflicting a grave injury upon all the parts through which it tears its way. The conditions so produced are serious and long continued.

In severer cases a part of the chest-wall may be destroyed, being driven inward by a massive piece of shell casing, or being swept away by a glancing blow. Few cases reach a base hospital in France, and still fewer, of course, in England, when any large

part of the parietes has been lost. Such cases die in advance stations up the line from shock or from hæmorrhage. The few that I have seen at base hospitals were all heavily infected and suffered much distress. Their condition is a powerful argument in favour of the early closure of all parietal wounds, wherever possible.

The Injured Lung.—The effects produced in the lung are strictly comparable to those produced in other parts of the body by the various forms of projectile. The points of entrance and of exit in the case of perforating wounds bear all the appearances of those seen in the soft tissues of the thigh. The entrance wound is small, even punctate; the orifice of exit is large, more irregular, and bears signs of greater injury and of a tendency to protrusion of wounded parts. Along the track of the missile there are the same evidences of diffused injury. The parts around are bruised and lacerated; there is a hæmorrhagic pulmonary infiltration of varying but often wide extent. The part of the lung giving on to the track is contused or dead, and such tissue offers here as elsewhere the most favourable opportunities for bacterial invasion and growth. Postmortem examinations of wounded lungs generally show that the track of the projectile, whatever it may have been,

is rectilinear. There are no fissures or rifts radiating from the main track, nor any hidden pockets shut off from the central channel. Several tracks may be found in close approximation when many fragments of metal have entered. The bronchi of large or medium size seem to escape injury in the majority of cases. In the path of the projectile blood is extravasated in the earliest hours; in later stages pus may be found.

The injury to the damaged lung is not, however, confined to the path of the bullet and the parts immediately adjacent. The distant parts of the lung or the pleura bear traces of lesions, due to the force with which the parts are struck or to the sudden constriction of the chest, followed by its instant expansion, upon the impact of a volume of compressed air caused by the explosion of a shell. There may be hæmorrhages by "contrecoup" in the upper lobe if the lower is wounded, or in the lower if the upper is injured, or in both if the projectile has passed near the base of the lung. These, as Duval has shown, may be recognised at once by the opacity seen on the radiograph; and I have found in later operations many recent adhesions of the pleura over parts that could by no possibility have met with a direct assault and evidences of intrapul-

monary hæmorrhages. These conditions are of the same order as those described in an early fatal case by Latarket. He has found a massive congestion of the whole lung, a sort of diffuse hæmorrhagic infiltration involving the entire organ, in a case in which a bullet wound was inflicted at close range.

Such meagre postmortem experience as exists confirms the impression that is derived from the clinical examination of operated cases, that wounds of the lung heal rapidly and kindly.

The Opposite Lung.—It is a new fact, learned during this war, that the opposite lung suffers damage also. Such lesions are frequent, in the severer cases probably constant. They consist in small or large hæmorrhages beneath the pleura or in the substance of the lung. These may be followed by filamentous or by firm adhesions between the visceral and parietal pleura and by patches of solidity in the lung itself. In a late stage the lung may present all the evidences of a bronchopneumonia at one point or in many. The increased activity imposed upon the lung by the restricted function of that which has been wounded no doubt renders it an easy prey to any malady. The presence of an infected expectoration in the trachea may lead to the inhalation of purulent or septic material into the uninjured lung.

These conditions often improve very rapidly when the injured side is treated by aspiration of a large hæmothorax, or free drainage of an empyema.

Hæmorrhage.—When a missile enters or traverses the chest, any of the vessels contained therein may be lacerated. If the larger vessels in the mediastinal cavities or in the root of the lung are divided, the loss of blood is so copious and rapid that death results at once and the patient does not reach even an advanced aid post.

In the cases not immediately fatal the blood comes, in the very great majority of cases, from the lung tissue. Henry and Elliott, as a result of careful investigation of the thoracic walls and the lung in 78 postmortem examinations made on the subject of hæmothorax, came to the conclusion that the bleeding had been of pulmonary origin in the great majority of cases.

Apart from the cases dying instantly from hæmorrhage, the deaths in the first forty-eight hours are all due to loss of blood from lung tissue. Both in the French and the English armies precocious operative measures are being adopted in such cases with a degree of success that encourages a wide adoption of this practice. If death does not occur speedily from hæmorrhage, a recurrence of bleeding is not often

seen. Patients rarely die from hæmoptysis, and secondary hæmoptysis is extremely infrequent. The occurrence of hæmorrhage through the wounds of entry or of exit is probably responsible for the erroneous belief that it is from the chest-wall, from the intercostal vessels, that the blood is lost.

Dolbey records one very remarkable case of gross hæmorrhage resulting from a wound of the axillary vein. The chest filled with blood from the torn vessel, but after two large aspirations, the wound in the vein healed. There was also an aneurysm of the axillary artery treated by ligation of the subclavian artery successfully.

Hæmothorax.—When blood escapes into the pleural cavity, what happens to it? According to Elliott and Henry, "it appears probable that clotting always takes place—and very early—through the action on the blood of the ferment liberated at the surface of the wounded tissues; the clot may be (*a*) complete and massive, forming a soft and persistent clot; (*b*) massive, but with an early and fairly extensive separation of the yellow serum from the clot; (*c*) interfered with by the churning movements of respiration" (and of the heart?), "so that the fibrin is whipped out in layers which cover the pleural surfaces, while the serum retains most of the red corpuscles in suspension."

The amount of blood extravasated into the pleura varies very much—from a few ounces up to four or even five pints. The escape of blood is hindered and at last arrested by collapse of the lung and by the pressure exerted by the blood which has already flowed into the pleural cavity. The response of the pleura to the contact of blood is expressed in an inflammatory reaction which also helps in some degree to seal the leaking orifice, though it also increases the mass of fluid lying in the chest. In fact, the admixture of fluid effused from the pleura accounts for the fact that in many cases the condition of the combined fluids does not conform with that seen when only blood is extravasated.

Hæmothorax in itself, though disabling enough and productive of such general effects as the loss of a large quantity of blood necessarily entails, is not dangerous to life, apart from infection. The bacteria chiefly responsible for this hazardous complication are, according to Duval:

A. Aërobic
- 1. Derived from the respiratory tract:
  - Pneumococcus.
  - Staphylococcus.
  - B. tetragenus.
  - B. of Pfeiffer.
- 2. Derived from the wound:
  - Streptococcus.
  - B. coli.

B. Anaërobic { Bacillus of Welch.
B. sporogenes.

The most common association is of the Bacillus coli with the gas gangrene bacillus.

The frequency of infection may be gauged from the figures given by Captain Henry. Out of 500 specimens of fluid obtained by tapping, in the ordinary routine of work 195 were found to be infected, and of these, 87 were infected by anaërobic organisms. These may be distributed from the first throughout the bulk of fluid, or they may be retained in the fibrinous mass at the bottom of the pleura for a longer or shorter period, being disseminated at last through the supernatant fluids as a result of the respiratory movements. This accounts for the fact that the first puncture made for diagnostic purposes was found by Elliott and Henry in 50 per cent. of pure infections by anaërobic bacilli to be negative. The syringe introduced into the upper fluid part of the hæmothorax may discover no organisms, whereas one made lower down, into the more solid fibrinous clot, may give positive results. The infection may be derived from the projectile or clothing carried into the wound at the moment of the infliction, or may be derived at a later stage from the focus in the lung or from the suppurating external wound. P. Duval, in the

Somme battles, had charge of 193 cases of gunshot wound of the chest. Of these, 49 were due to bullet wounds, none of them had an infected hæmothorax, there were 33 perforating wounds from shell fragments, and among these were 6 of infected hæmothorax—18 per cent. There were 111 penetrating wounds; among these were 28 of infected hæmothorax (24 per cent.).

TREATMENT

Upon one point all those who have been responsible for the treatment of a patient with a chest wound are in complete and confident agreement. The earliest and the most perfect immobilisation is necessary. Movements of all kinds are to be avoided, and therefore retention of the wounded man at the Casualty Clearing Station for many days is a paramount necessity. The fact that in the first two days the deaths are due chiefly to hæmorrhage and in later stages to sepsis must direct the timely and appropriate treatment. Early operations for the purpose of arresting hæmorrhage from the lung tissue have been tried out in certain hospitals in either the French or the British zones; but so far as the results of the work have gone, they appear to justify a continuance of, and indeed a general adoption of, the principle

of early direct treatment of the wound. It is, I think, largely owing to the advocacy and to the successful practice of P. Duval that an earlier surgical attack is now considered necessary upon the graver kind of lung case.

Immediate intervention, according to Duval, should comprise:

I. Closure of the chest-wall in cases of "open thorax."

II. Thoracotomy with suture or plugging of the wound in the lung in case of grave hæmorrhage or of threatening asphyxia.

III. Treatment of progressive surgical emphysema.

I. Closure of the chest-wall, an operation practised by Larrey in the Napoleonic wars, has as its aim the suture of the muscles and skin in order to avoid traumatopnœa, pneumothorax, and a continuing infection of the pleura from the suppurating external wound. The principles are those guiding the surgeon in all similar wounds elsewhere; the results in the saving of life and suffering are incalculable. The gravity of the cases of "open thorax" can hardly be exaggerated. When a part of the chest-wall has been torn away the lung, often bruised or lacerated, is exposed, it retracts toward the hilum, and leaves gaping and bare a huge cavity wherein putrefaction

may occur and a large surface from which absorption can take place. It is most urgently necessary to close such ghastly wounds if it is physically possible. Gregorie has accomplished this in 17 cases, of whom 16 recovered.

II. Thoracotomy is formally indicated in all cases of wound of the lung causing hæmorrhage. Suture of the lung tissue affords perfect hæmostasis. When any foreign body, projectile, or sequestrum is felt, the lung is incised over it if necessary, and after extraction of the foreign body, the wound is stitched up accurately. Any blood lying in the pleura is carefully evacuated, perfect cleansing of the cavity is insured, and the wound is closed, it may be after a gentle wiping of the parts with ether. There is no need for drainage.

III. In the treatment of progressive emphysema closure of the wound in the lung will shut off the channel through which the air escapes into the tissues. Multiple skin incisions will relieve the tissues already distended and crepitant. In cases of simple penetrating wounds a cleansing and excision of the wounds, followed by a complete approximation of the edges, is all that is necessary. In many cases even excision is not required; the points of entrance and of exit may be cleaned and covered with a sterile dressing.

When a hæmothorax is present, no interference, as a rule, is needed for some days. There may be exceptions to this rule when the rapid or the large accumulation of fluid is causing urgent dyspnœa which threatens the life of the patient. The dangers of early aspiration of the fluid are, of course, related to the reopening of the pulmonary wound, which, lightly sealed, may bleed afresh as the lung expands. At the end of a week or thereabouts aspiration of the blood has probably a most beneficial effect upon the lung, allowing it to expand much more rapidly than would otherwise be possible, and preventing the formation of those dense crippling adhesions which may embarrass the free action of the lung for a long time to come, or even permanently. Operations on cases in England, in which the blood has been left in the pleural cavity, reveal an extreme density and a wide extent of adhesions. *X*-ray examination also demonstrates the firm union that is formed between the two layers of the pleura. Withdrawal of the fluid is therefore most desirable; its replacement during aspiration by oxygen allows more fluid to be taken, and causes the minimum of distress to the patient.

In cases of large hæmothorax which presumably have remained sterile, and in which no active treatment has been adopted, there is a protracted period

of incapacity of the lung. I have seen such cases many months after the injury in which the percussion-note was still dull, the breath-sound was absent or diminished, the chest flat, and the respiratory movements very restricted. On examination by *x*-ray a greatly thickened pleura was diagnosed and immobility of the diaphragm observed on the affected side. If aspiration is performed, the appearance of the fluid gives valuable information as to its condition in respect of bacterial infection. If the fluid closely resembles new port wine in colour, it is free from infection; if it is clear and almost colourless, the amount of blood contained is small; most of the fluid is then the result of a pleuritic effusion. A turbid fluid like weak cocoa, or an effusion with any suspicion of offensiveness, indicates that infection is present and that the condition is one to be treated as an empyema.

When a hæmothorax has become infected, then thoracotomy is necessary. In the early period of the war the operation was practised on the lines of the civil operation for empyema. A short piece of rib was excised, the putrid and most offensive fluid evacuated, and a large drainage-tube introduced. Such cases remain sometimes for weeks, even for months, in the open wounds. Tuffier has modified profoundly

for the better the treatment of these tedious and most trying cases by adapting to their needs the Carrel-Dakin technique. The operation, in so far as resection of the rib and evacuation of the fluid are concerned, is precisely similar to the procedure in cases of empyema, but instead of one large tube, several small tubes threaded with wire are placed over the cavity at well-judged intervals. Their position and proper distribution may be confirmed if an *x*-ray is taken. A little loose gauze is packed into the wound, and a safety-tube for drainage of excess fluid in one angle of the incision. Dakin's fluid is instilled in the usual manner. At the end of ten days all discharge (there is rarely more than an extremely small quantity after the first two days) has ceased, and the tubes are therefore removed and the wound closed.

There is no doubt that many cases of suppurating hæmothorax would do better if operated upon quite early by a wide opening of the chest and a complete clearing away of all masses of clot and pleural lymph, often so tenaciously adherent, and by removal of any projectiles. Patients so operated upon or operated by the older methods linger on in unsatisfactory conditions for such long periods at home that every fair opportunity that offers for curtailing the tedious and not wholly safe period of their convalescence must be

embraced. The Carrel-Dakin technique will here find one of its most valuable indications. This is only to bring the treatment of wounds of the lung into line with that of wounds elsewhere. The surgeon no longer allows infection to be well established in the wound; his aim is to attack by approved methods [the free opening of the wound, the excision of all dead or contaminated tissue, the removal of all fragments of clothing, of all projectiles, and of all foreign bodies] and then to secure the earliest possible closure of the wound which remains. No less an ideal and no less scrupulous a practice should guide him also in the treatment of wounds of the lung and pleura. The time has gone by when he can justly allow an infection to become deeply ingrained before adopting those tardy, incomplete, and often ineffective methods with which he has been too long content.

What is the history of patients in whose lungs projectiles are retained? Our knowledge does not allow us as yet to answer this question fully. But a certain experience is not likely to be changed by a larger survey of cases. We may say with confidence that a rifle bullet or a small piece of shell casing may be retained for months or years without causing distress and without affecting appreciably the normal func-

tions of the lung in which it lies buried. But with large or irregular pieces of shell the case is different. I have seen many patients suffering for twelve or eighteen months from cough, with hæmoptysis at intervals. In two cases the loss of blood was serious. And in many patients there is an increasing complaint of pain, dyspnea on exertion, and of expectoration of mucus.

For these reasons I have recently given special attention to these patients and have submitted a number of them to operation. The results so far entitle me to say that it is probably a safer, and it is certainly a speedier, procedure to submit all patients in whose lungs a large projectile is retained to operation rather than to leave them untreated. In almost every case operated upon the projectile has been dropped at once into a culture-medium: with one exception all missiles were infected; the organism most commonly found was the staphylococcus.

The following are the details of the procedure adopted for the extraction of bullets from the lung. Its principles have been firmly established by the work of Pierre Duval. The operation is performed under anæsthesia induced by ether and oxygen. A preliminary injection of morphin and atropin is given about half an hour before the operation.

The patient lies flat on his back, with the arms at the sides. A curved incision, about 5 or 6 inches in length, is made exactly along the line of the fourth rib. The fibres of the pectoralis major are split, and the pectoralis minor is separated from the rib. There are many points of hæmorrhage requiring a clip or a ligature. All must be carefully secured so that there is a perfectly dry field. The rib and the costal cartilage are exposed for a distance of not less than 5 inches. An incision is made through the periosteum, midway between the upper and lower borders, and this membrane is stripped from the rib on both surfaces. A curved raspatory of Doyen's pattern is very useful for the purpose. In my earlier operations I cut through the costal cartilage and then divided the rib with forceps so that a length of 4 to 5 inches of the rib could be removed. In later operations I have freed the inner end of the rib after division of the cartilage, have passed a strip of gauze beneath it, and pulled it upward and outward, causing a fracture, often of the "greenstick" type, a little behind the middle of the rib. In this way the rib may be saved and replaced at the end of the operation. This, however, is not a point of great importance, for when the periosteum is left, a new rib is formed very rapidly, and the chest-wall soon becomes as

firm as ever. Care is taken in excising the rib and in lifting it away not to wound the pleura, which must be separated widely from the ribs above and below, to the inner and the outer side of the wound. Unless this is done, accurate closure of the pleura later on, always difficult, will be impossible. A retractor is now placed in the wound to widen the interval between the ribs above and below. Any abdominal retractor will do, but the best instrument I have used is that invented for this special purpose by Tuffier. As wide a gap as possible is made, so that the whole hand can easily be passed into the chest.

The pleura is now incised along the line of the rib, and air enters freely and at once into the pleural cavity. As a rule, this causes no disturbance and does not alter the rate of the respirations or of the pulse.

The hand is now passed into the chest cavity. Adhesions of the lung to the parietal pleura may be encountered. These are sometimes very slender and easily broken through. At times they are tough and strong and are with great difficulty severed. If they are numerous or thick and tough, bleeding may occur quite freely for a minute or two. With gentle pressure from a hot, moist swab the oozing is soon checked. In a case where a projectile was in the base of the right lung posteriorly, the whole of the lower

lobe and a great part of the upper lobe were most intimately adherent to the parietal pleura and patches of the lung felt solid. The adhesions, however, separated in just the same way as adhesions within the abdomen separate, by gentle pressure and stripping. Thoracic adhesions bleed, I think, far more freely than those encountered in the abdomen. When all are loosened, the collapsed lung lies free within the pleural cavity. It may now be seized with the fingers or with a special light form of clip and drawn up to the anterior wound, and, little by little, be coaxed out of the wound. It is surrounded, as it appears, by warm cloths soaked in normal saline solution. When a lobe of the lung is freely delivered, it is palpated from top to bottom. Any projectile embedded in it is felt, as a rule, at once. Even little sequestra blown in from a rib may be recognised without any difficulty. These foreign bodies are as easily recognised as the particles of gritty sand in a new sponge. When the projectile is felt, the part of the lung containing it is made prominent, the lung tissue lying over it is incised, the metal removed, and the wound sutured. Deep stitches of catgut are passed through the lung substance, and with gentle tension act as a hæmostatic. If necessary, very fine catgut sutures may be used to secure

the accurate apposition of the pleural edges. If there is any bleeding from the collapsed lung, it is slight and easily controlled, but precision in suture is most desirable, for expansion of the lung will rapidly be secured when the operation is completed. If there are two or more particles of shrapnel or shell casing in the lung, they are all dealt with in the same way. I have once incised the hilum of the lung and stitched it up without difficulty. When the sutures are completed, the lung is replaced, the cavity of the pleura most carefully dried and emptied, and a gauze swab wet with ether wiped over the visceral pleura and over any adhesions which may have been separated. The retractor is removed and the parietal pleura now stitched up. This is quite the most difficult part of the operation; indeed, I have not been able to close the pleura accurately unless this membrane has been stripped up freely from the chest-wall before being incised. The rib, if it has been turned back, is replaced, and fixed in position by a suture through the costal cartilage. The muscles are carefully sutured, and the wound edges accurately approximated without drainage. The closure of the wound should be so carefully done as to seal the chest hermetically. When the dressing is applied, a two-way needle may be plunged into the chest, and the ether and air ex-

tracted therefrom. The lung then rapidly expands, and faint breath-sounds are heard at once.

CONCLUSIONS

The following general conclusions may be stated:

1. The approximate mortality from gunshot wounds of the chest at all parts of the line of communication is 20 per cent.

2. The causes of death are hæmorrhage, as a rule, within forty-eight hours, and sepsis after the fourth or fifth day.

3. The local conditions in wounds of the chest-wall and lung are in all respects similar to those met with in wounds elsewhere. The missiles are the same, their destructive effects upon the tissues are the same, and the infecting organisms are the same.

4. The lung tissue is more resistant to attack than are many other tissues. The opening of the pleural cavity and the resulting exposure of a large serous sac to infection and all its consequences add, however, a danger of the most threatening character.

5. The chief essential in the treatment of all cases of penetrating wounds of the chest is rest.

6. In clean perforating wounds of the chest rest, together with the cleansing and dressing of the wound

of entrance or exit, will lead to the recovery of the great majority of cases.

7. In cases of "open thorax" the earliest and most complete effort possible must be made to secure closure of the wound after an appropriate toilet.

8. In those rare cases of grave hæmorrhage, when hæmoptysis is present or when the blood escapes by the wound, a direct access to the source of the bleeding must be obtained, when all contingent circumstances permit, and the wound in the lung must be treated by suture, preferably, or by plugging of the cavity from which the blood escapes.

9. In cases of hæmothorax, when the blood effused is small in quantity and remains sterile, no active measures are necessary unless absorption is long delayed. Aspiration, repeated, if necessary, may then be performed.

10. In cases of hæmothorax, when the blood effused is large in amount and remains sterile, aspiration after the seventh or eighth day, or earlier in cases of urgent dyspnœa, certainly hastens convalescence, permits a more rapid expansion of the lung, and prevents the formation of firm adhesions which may permanently cripple the free movements of the lung.

11. In cases of hæmothorax, whether the amount of blood is small or large, when infection takes place,

open operation is necessary. Early operation, especially of the Carrel-Dakin technique, if adopted, saves many weeks of tedious convalescence and permits of a more perfect functional recovery.

12. Small foreign bodies or rifle bullets embedded in the lung often cause no symptoms: they become encapsulated and may safely be left.

13. Larger foreign bodies retained in the lung may cause distressing or disabling symptoms for long periods. In such cases removal after resection or elevation of the fourth rib through an anterior incision will allow of the safe removal of the projectile from any part of the lung. Pieces of metal so removed are generally infected.

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